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The ecology of the smelt, Osmerus mordax mordax (Mitchell) in Great Bay, New Hampshire

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THESIS

UNIVERSITY OF
NEW HAMPSHIRE

THE ECOLOGY OF THE SMELT,
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IN GREAT BAY, NEW HAMPSHIRE

by

STANLEY BRADLEY KROGHMAL

MASTER OF SCIENCE

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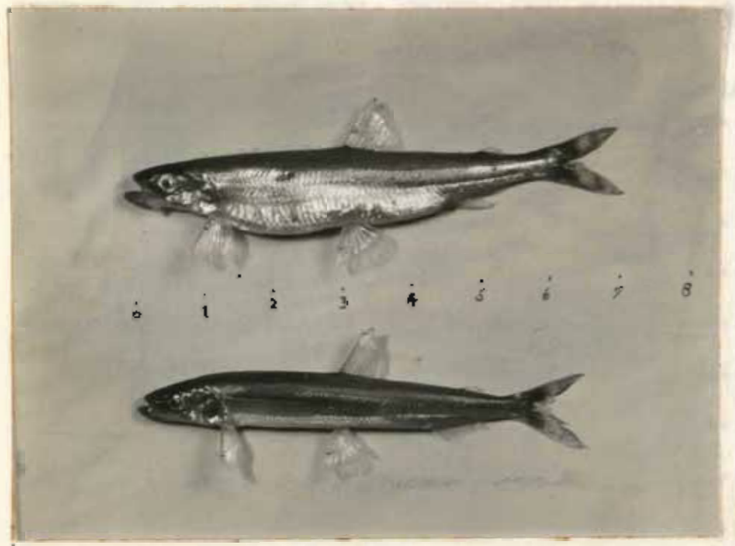

Smelt taken from the Exeter River in Stratham, N.H. on April 15, 1949. Top figure is unspent female, lower that of a male. Both fish represent the three year old class. Scale shown is in inches.

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I. INTRODUCTION

Great Bay, New Hampshire is an inland body of water having an irregular shoreline with numerous rivers and many small streams flowing into it. Great Bay proper is approximately four miles wide and six miles long located in the northeast part of Rockingham county. Little Bay is a smaller body of water about two miles long and three quarters to a mile and a half wide. The long axis of Little Bay lies east and west while that of Great Bay lies north and south. Little Bay joins Great Bay on its western end while on the other side to the east Little Bay flows into the Piscataqua River and hence out to the Atlantic Ocean.

Great Bay has no direct outlet to the ocean but tidal movements up the Piscataqua River reach it through Little Bay. Tide water extends into all the rivers for some distance so there is a gradiant of salinity from fresh water out to the sea.

In the study of the smelt the entire Great Bay drainage as shown by map on page 10 was carefully studied. Well over 5000 miles were covered by automobile and many more by foot and boat in the course of this survey. Since the smelt fishery has practically disappeared on the Bellamy, Cocheco, Salmon Falls, and Upper Piscataqua River due to the pollution, and perhaps other reasons; effort was naturally diverted and concentrated to Great Bay proper. The total tidewater area included within

the study is approximately 7500 acres. This includes Great Bay, Little Bay, Oyster River, Exeter River, and Winnicut River. Not to be overlooked are the many smaller streams so numerous and important when any anadromous species is being considered. Section III of this report deals with the various rivers in more detail.

Great Bay and its fishery are famous in history. In days gone by it was the scene of much activity. This area was settled by white men because here in this region were teaming millions of fish which contributed so much to their support and commerce. Not only smelt were abundant but also cod and haddock, striped bass, shad, mackerel, herring, eels, salmon and many others not to mention all sorts of shellfish such as lobster, oysters, clams, etc.,

It was from the river that men derived their livelihood and to this they also turned for transportation. How times have changed! Our rivers and Bay are now used but little for transportation. As for men deriving their livelihood from fishing, it was noted this past season that most of the weir smelt fishermen did not catch enough to pay for their netting, time, or labor.

The history of this region records the abundance of fish life of the past. Since the pioneer days the smelt have been one of the most abundant and popular fish of Great Bay. Today the smelt fishery is still the most important but in spite of their former abundance, smelt are decreasing at an alarming rate. No longer can smelt be taken by the ton for

the Boston market where "Great Bay Smelt" enjoyed an enviable reputation and always commanded the maximum price.

Great Bay perhaps can still be improved and its former teeming fish life be restored in some measure. Its naturally endowed physical character and plentiful supply of food material to sustain and cultivate all types of fishlife is not entirely gone. However, no one can expect to have a reasonable amount of success with any program to increase the fish population, especially smelt, until this pollution condition is cleared up in the various river tributaries leading into the Bay.

At least three different agencies have been engaged in determining the pollution in the past several years. These are: The State Board of Health, the Biological Institute and the Biological Institute in cooperation with the U. S. Public Health Service. Because the understanding of this topic is so important in regard to the profound effect it has on the smelt spawning areas it will be taken up in more detail later on in this paper.

During the summer of 1947 and 1948 the author started biological work on Great Bay in the form of a botanical survey for the State Fish and Game Department, but most of the present study was made during the 1948-49 school year. One must concede conditions vary from year to year and that a conclusive study would have to be carried over a much longer period. Therefore, the results of this one year's work will only indicate some trends. It is hoped that the results of

these findings will stimulate interest in this problem and that others may continue research work along these lines.

II. REVIEW OF THE LITERATURE ON THE LIFE HISTORY OF THE SMELT.

Wherever smelt occur they abound or once abounded. Unfortunately the literature on these same smelt is not as abundant. In the course of study it was somewhat surprising to find so little has been published concerning the habits and life history of the smelt.

Previous to the extensive paper by Kendall "The Smelts"--(1926), almost nothing was known, or if known had not been published. Kendall at one time was impregnated with the ambition to write a monograph on the smelt and smelt-like fishes of the world. Although this was never realized, due to more or less prolonged interruptions by other work in which smelt had no part, Kendall was able to compile practically all the available information up to his time. The published material he used was for the most part scattered often in brief notes through many publications. His work included a fine bibliography. The treatment is on the smelts of the Atlantic Coast only, and particularly on those of the eastern United States. Both marine and fresh water species are considered.

A contemporaneous paper of similar great interest to us in New England, which is not mentioned in Kendall's bibliography, is Bigelow and Welsh's "Fishes of the Gulf of

Maine". This appeared as a Bulletin of the United States Bureau of Fisheries, Volume XL., part I. Nine pages are devoted to the smelt family. Similarly Kendall's paper appeared as a Bureau of Fisheries Bulletin, Volume XLII, Document number 1015. Needless to say neither of these are now available for sale by the Superintendent of Documents, Washington, D.C.

Other literature frequently cited is as follows: Creaser "The Establishment of the Atlantic Smelt in the upper Waters of the Great Lakes." (1925)--Green, "The Smelts of Lake Champlain", (1930)--Langlois, "Notes on the Spawning Habits of the Atlantic Smelt," (1935)--and Richardson, "The Occurrence of the Nuptial Tubercles of the Female of Osmerus Mordax (Mitchill)- 1942.

There has been but limited work done on the smelt in the Great Bay region. Warfel, Frost, and Jones in 1942 published "The Smelt, Osmerus Mordax, in Great Bay, N.H." Their work primarily involved the analyzing of a spawning run of anadromous smelt for age, size, sex ratio, and sexual dimorphism. Goodrum in his Thesis "Distribution of Fishes of Great Bay." submitted to the University of New Hampshire mentions some of the high points in the life history of the smelt.

As yet not published but in press as this Thesis is being submitted, is Jackson's comprehensive treatise "The Fishes of Great Bay and Its Tidal Rivers". This piece of work in bringing together all the species of this region

culminates 40 years of study of the fishes of Great Bay and the costal waters of New Hampshire by its author. A generous portion of this report is devoted to our smelt resource in which Jackson has shown intense interest.

Mention should be made of Hoover's report: "The Spawning Activities of Fresh Water Smelt, with Special Reference to the Sex Ratio (1936). This work was done on smelt throughout their seasonal run in Black Brook, a tributary of winnisquam Lake, near Laconia, New Hampshire. It is quite apparent that the methods used by Hoover in a fresh water environment can be readily adopted for observation on our marine smelt.

Most of the recent investigations pertaining to the smelt fishery have been done in the Canadian Provinces, notably New Brunswick. Smelting is one of the largest industries there and research has kept abrest. The bibliography includes some of the papers from our friends to the north.

III. DRAINAGE SYSTEM OF THE GREAT BAY AREA WITH ECOLOGICAL NOTES

The southeastern portion of New Hampshire is in what is called the Coastal Watershed. This portion of the State is drained by a series of rivers which either enter directly to the Atlantic Ocean or into Great Bay which already has been mentioned as a tributary to the Piscataqua River and ultimately the Atlantic Ocean. It is these rivers that flow into Great Bay that will be considered in more detail in the sections that follow.

The entire Coastal Watershed has an area of 821 square miles with approximately 700 square miles in the Great Bay drainage. These figures are supplied by the State Planning and Development Commission. It extends from the coast on the southeast into Brookfield and Wakefield on the North. From the Maine line to the east, it extends westward to Alton, Northwood, Deerfield and Candia. The height of land to the south is found in Chester, Hampstead, Danville, Kingston and Kensington.

1. Winnicut River

The first river to be considered is the Winnicut which drains into Greenland Bay from the south. This is a fairly small stream not navigable at low tide. It is relatively free from pollution since it runs for the most part through woodlands. Its length from tidehead is approxi-

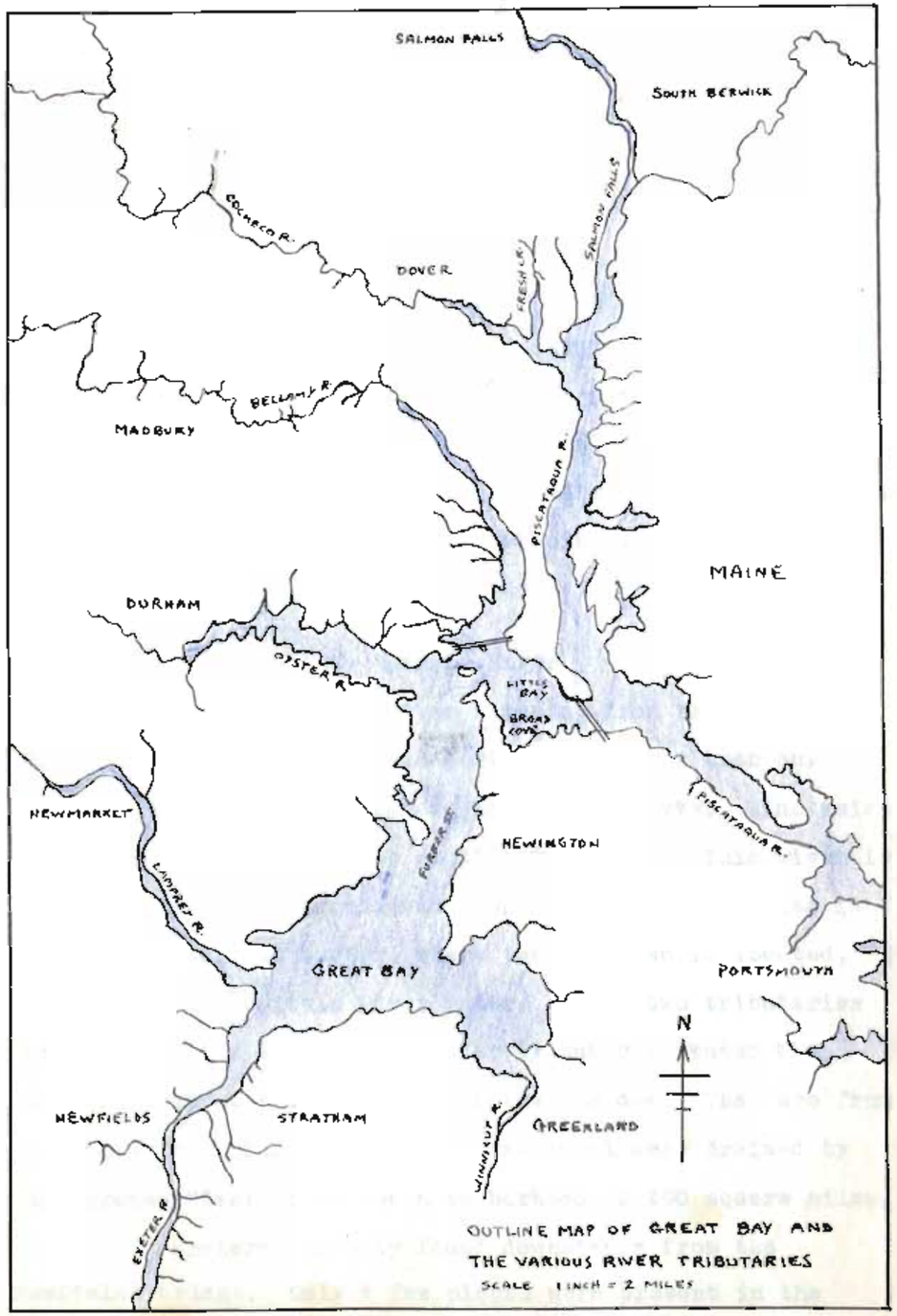
mately seven miles. About 20 square miles is drained by this system.

The tidal portion is about a mile in length, with a narrow channel filled for the most part with Spartina and Typha. The lower part of the tidal section below the railroad tracks as shown by U.S. Department of the Interior Geological Survey Chart appended is covered with soft-flocculent mud. This is a factor affecting Great Bay fish life caused in part by erosion and destruction of Zostera which releases silt. The distribution of Zostera is given for the Bay Area.

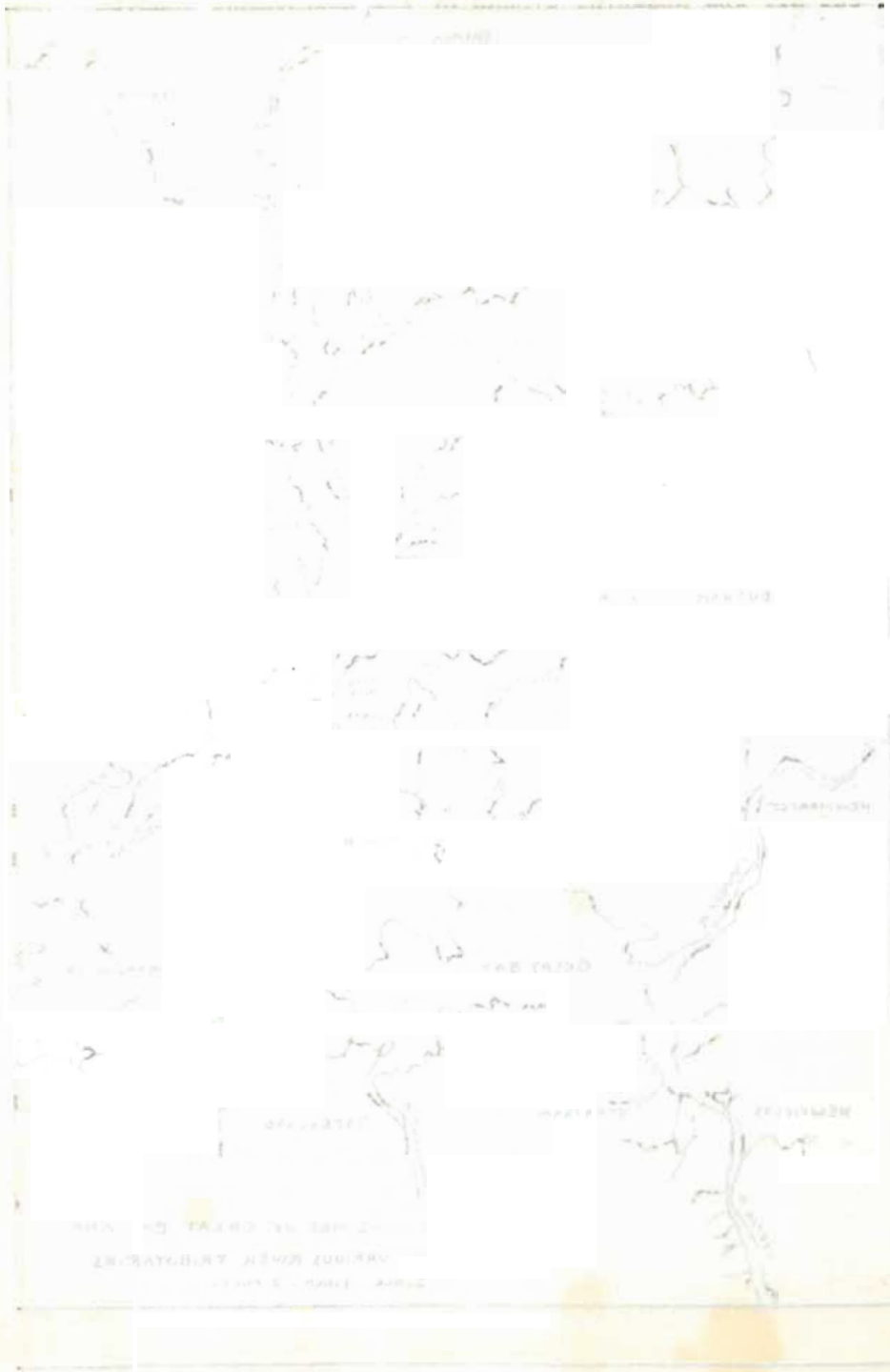
Although no Zostera was found in the Winnicut River, it nevertheless has made a remarkable come back in most of the other rivers and on the western side of the Bay as shown by map on page 13. Prior to 1931 Zostera was by far the most abundant plant species found in our brackish-water Great Bay. The sudden disappearence of this dominant stabilizing influence in the biology of these tidal waters is too well known to warrant repetition at this time.

Currently there are no obstructions on this river, since the dam washed out several years ago. It is understood plans are now underway to rebuild this dam. Plans have already materialized to the point where gravel is being carted in for construction. The active Piscataqua Fish and Game Club, with their club house near this dam site, have on their agenda proposals for a fishway.

It would be unfortunate to have this planned dam



OUTLINE MAP OF GREAT BAY AND THE VARIOUS RIVER TRIBUTARIES
SCALE 1 INCH = 2 MILES



cut off the spawning ground of the anadromous species. Upstream from tidehead, the muddy channel yields to an excellent rocky and gravel bottom condition which in turn grades into a finer gravel and sand as we ascend. No smelt were observed to use this stream for spawning this season, but alewives utilize its entire length.

There are at least ten other brooks varying in size from one mile to five miles in length which drain into the southeast end of Great Bay. All are relatively free from pollution of any kind and when considered totally form a large and important potential spawning area. These streams on checking were all found to have suitable bottoms for spawning.

2. Exeter River

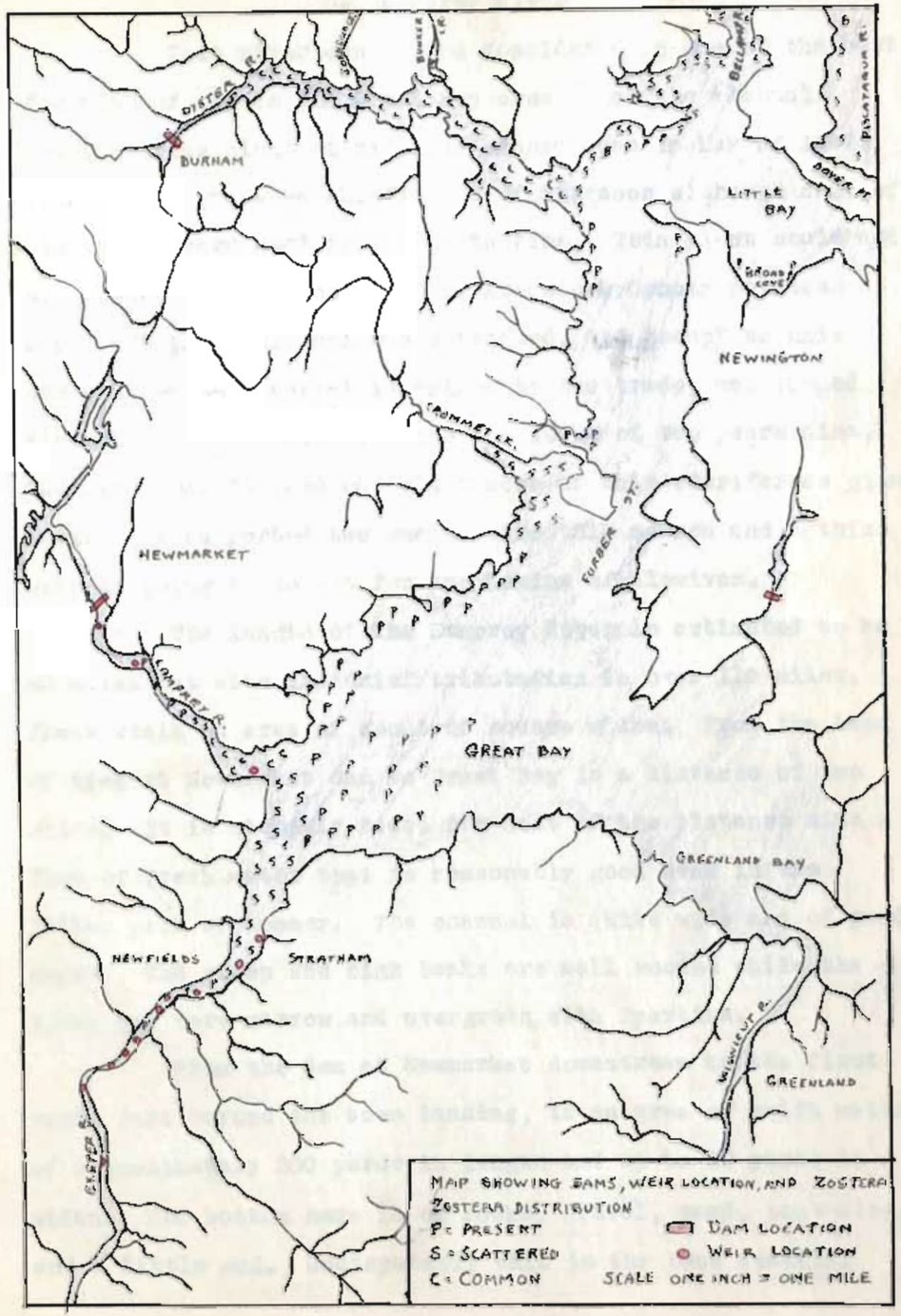
The only other river entering from the south is the Exeter River. The tidal portion is longer than any of the others and consistantly supports more weirs. Nine weirs were set up and fished for smelt this season. This river is 43 miles long, but considered with its many tributaries is over 60 miles. At Exeter, where the only dam is located, Great Brook and Little River enter. These two tributaries are seven miles long. Five other tributaries enter the Exeter River at various points below the dam. They are from one mile to 5 miles in length. The total area drained by the Exeter River is in the neighborhood of 100 square miles.

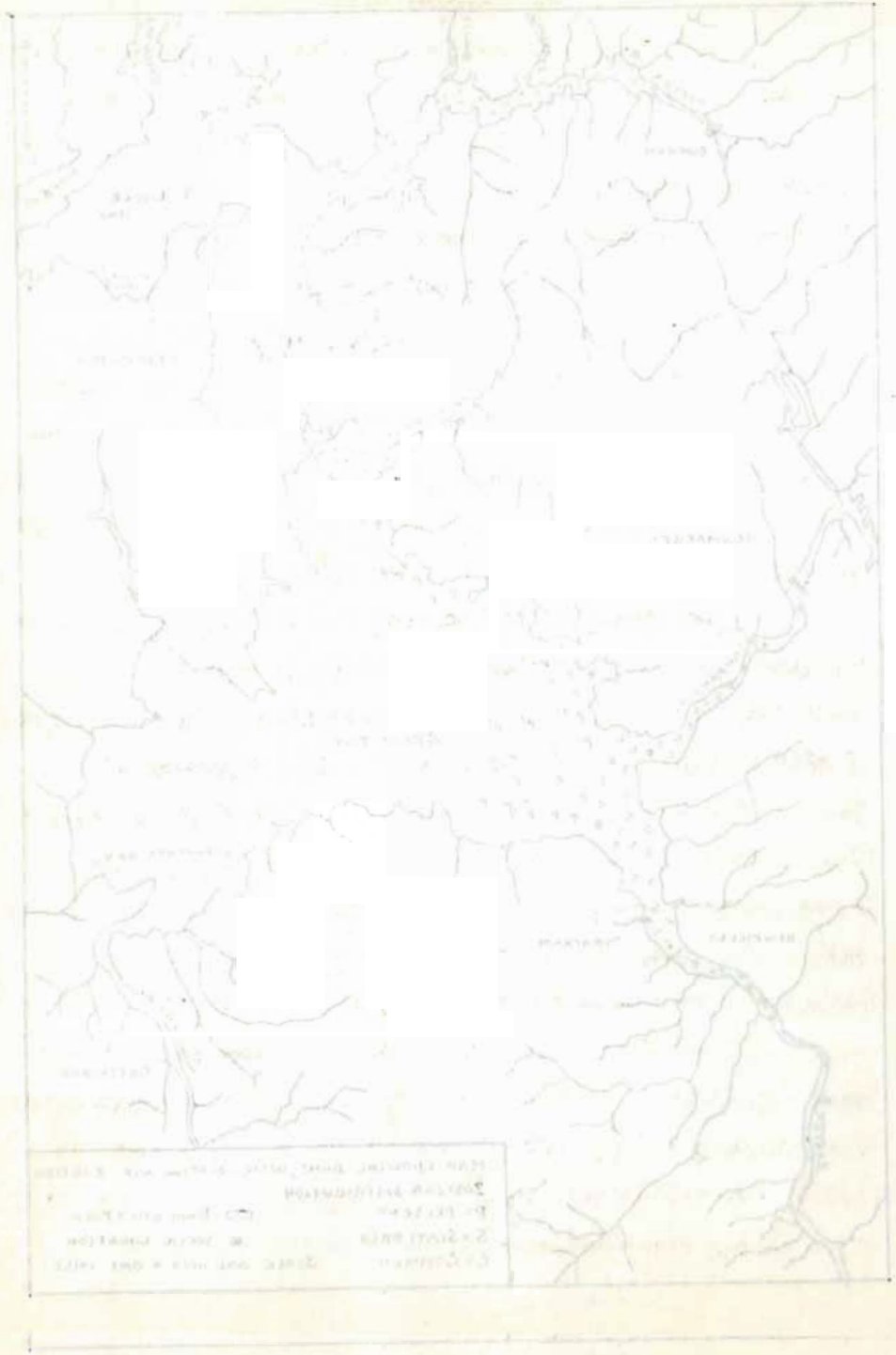
Zostera was only found downstream from the Newfields bridge. Only a few plants were present in the

immediate area of the bridge, but they proved to be somewhat more common as the channel was checked bayward. Three letters are used on the map on page 13 to represent Zostera distribution. "P" for present is meant to show isolated patches of Zostera, "S" for scattered should be interpreted to mean one quarter of available area being covered, and "C" for common indicated one half or over of the site is covered with Zostera.

The channel of the Exeter river almost reaches to the banks which are very narrow compared to those in the other river systems. These mud flat type banks very from soft to hard mud with occasional stretches of gravel and rock, especially around some of the sharp turns. Although the major part of the channel has a good depth, it was found to be filling in rapidly at the tidehead near the dam.

Pollution is high, both domestic and industrial. Exeter with a population of over 8500 uses this river for its raw sewage. Brenwood and Fremont are of much smaller size but nevertheless contribute also. The village of Newfields is located a short distance above the mouth and like the other towns uses the Exeter river to carry away its pollutants. The potent and abundant wastes from the various industries at Exeter offer the greatest offense. All of the spawn that was found in the Exeter River had turned white and was dead!


DISTER R.
BURNHAM
BUNKER CR.
BELLAMY R.
PISCATAQUA R.
BOWER M.
LITTLE BAY
GROAT COVE
NEWINGTON
FURBER ST.
NEWMARKET
LAMPREY R.
GREAT BAY
GREENLAND BAY
NEWFIELDS
STRATHAM
WINNICUT R.
GREENLAND
EXETER R.
MAP SHOWING DAMS, WEIR LOCATION, AND ZOSTERA
ZOSTERA DISTRIBUTION
P = PRESENT
S = SCATTERED
C = COMMON
DAM LOCATION
WEIR LOCATION
SCALE ONE INCH = ONE MILE



3. Lamprey River

This river can now be considered as one of the best for fish of any in the Great Bay area since the alcohol manufacturing plant at tidehead closed down in May of 1947. Alcohol was prepared chiefly out of potatoes although some of the grains were used from time to time. This plant could and did process sixteen carloads of Aroostook County potatoes a day. After the alcohol was extracted, the "soup" as this damaging waste material is called by the trade, was pumped directly into the river. With the lapse of two years time, the river has flushed out all traces of this odoriferous plant waste. It supported two smelt weirs this season and a third weir is going to be set for the taking of alewives.

The length of the Lamprey River is estimated to be 45 miles but with its chief tributaries is over 110 miles. These drain an area of about 60 square miles. From the head of tide at Newmarket dam to Great Bay is a distance of two miles. It is strongly tidal for most of the distance with a flow of fresh water that is reasonably good even in the latter part of summer. The channel is quite wide and of good depth. The steep and high banks are well wooded while the flats are very narrow and overgrown with Spartina.

From the dam at Newmarket downstream to the first bend, just beyond the town landing, is an area of swift water of approximately 200 yards in length and up to 30 yards in width. The bottom here is of rocks, gravel, sand, some clay, and a little mud. Undisputably this is the best spawning

ground of the entire Great Bay for smelt. More smelt were taken here in weirs and more smelt spawn found than at all the other stations combined.

Below the rocky and sandy area are found hard mud areas which in turn yeild to the soft mud type of bottom as the mouth of the Bay is approached. More Zosters was found in the lower part of the river than in the other rivers to the south of it. A check on the map on page 13 will show it being common at the mouth, scattered upstream from here and being only present halfway between the mouth and dam.

The large amounts of silt and sludge reported present by other investigators is now all gone. The raw sewage dumped into the river is carried out by the swift current and the sedimentation one would expect over the spawning area does not exist here now.

4. Oyster River

The Oyster River is of special interest to us in part because of its proximity to Durham. For this reason perhaps, any practical management to be considered might be initiated here since it could be very easily observed and the problems that would arise could be dealt with more efficiently than if the project were at some greater distance.

Although the total length of the Oyster River is only 14 miles with a drainage area of approximately 19 square miles, there is always a good flow of fresh water. This crooked river drains farmland and second growth woodlands with practically the only pollution of any kind from Durham itself.

The Durham Laundry located above the dam at tidehead is known to be dumping its wastes into the river. Before any experimental work is started it might be possible to arrange the disposal of this laundry material in a more satisfactory manner. At the present time the town of Durham is under way with a project to cut down its pollution by means of a sewage disposal plant.

The tidal portion of the Oyster river is about three miles in length. This is the distance considered from the dam at Durham to Half Tide Rock at the mouth. The channel depth averages six to nine feet for most of its length but is narrow with extensive flats extending to both sides with Spartina spreading at a rapid rate. Five streams enter the tidewater portion. From the north Beards Creek, Johnson Creek, and Bunker Creek flow while from the south we have Horse Brook plus an unnamed brook to the east adding their volume to the Oyster River.

There is a fine growth of Zostera in almost the entire river. It can be recorded as ranging grom scattered with for the most part common over the entire area. Of interest is the thrifty stands that can be found in Bunker Creek. This represents the only brook in the entire system having such an abundant growth for a stream its small size.

The flats are covered for the most part with a fairly hard mud. One does not sink as readily in this material when walking around in boots as in the scattered spots in the small bays where a soft flocculent mud is located. At the head

of the tide a contrasting bottom is encountered. From the old ship warf extending upstream is an area of approximately 400 feet long and 30 feet wide. The bottom consists of a few boulders, some rocks, much rubble, gravel, and sand. Were it not for the slime and mud covering a goodly part of this fine bottom material it might currently be an excellent spawning area for smelt. No smelt have been taken out of this area this season and likewise no spawn was found. Careful checks by experienced observers have similarly failed in the past three years to locate smelt spawn. The last authentic record for smelt eggs is that recorded by Professor Jackson of the University of New Hampshire in 1945.

5. Bellamy River

The Bellamy River drains the Madbury and lower Dover area. The twelve mile Mallego Brook is the single tributary of any size that flows into this river. The Bellamy River itself is about eight miles long. The total drainage area is 40 square miles. Although mostly farms and second-growth woodlands are drained much pollution is picked up at Sawyers. The industrial and the domestic untreated sewage of over 5000 people is heavy. When the portion at the dam at Sawyer's Mills was checked in 1948 for Zostera, the stench was nauseating and no sign of any plants of even the more tolerant types could be found in the river for about a mile downstream.

The river is generally sluggish including the tidal portion which is five miles long and which extends from

Sawyer's Mills to the Scammel bridge. The winding channel is bordered by extensive mud flats. These support a good growth of Zostera starting about a mile below the dam. As in all the other rivers, the encroachment of Spartina onto these flats is considerable. The bottom varies from a soft to hard mud with a very flocculent, muddy, and silty material washing back and forth with the tide. Natives claim this washed material was noticeably even more pronounced as recent as six years ago before the Zostera made its fine showing that we now have.

In recent years this river seems to have been deserted. Very little is made of its recreational potential as to boating, fishing and related uses. This perhaps follows the dwindling of fish life to almost the point of non-existence. Not an eel or a smelt has been taken this past season from this river following a check with the natives and personal observations. The headwaters and Varney Brook, entering from the north, have been systematically checked for both smelt and smelt spawn but with no avail.

6. Cocheco River

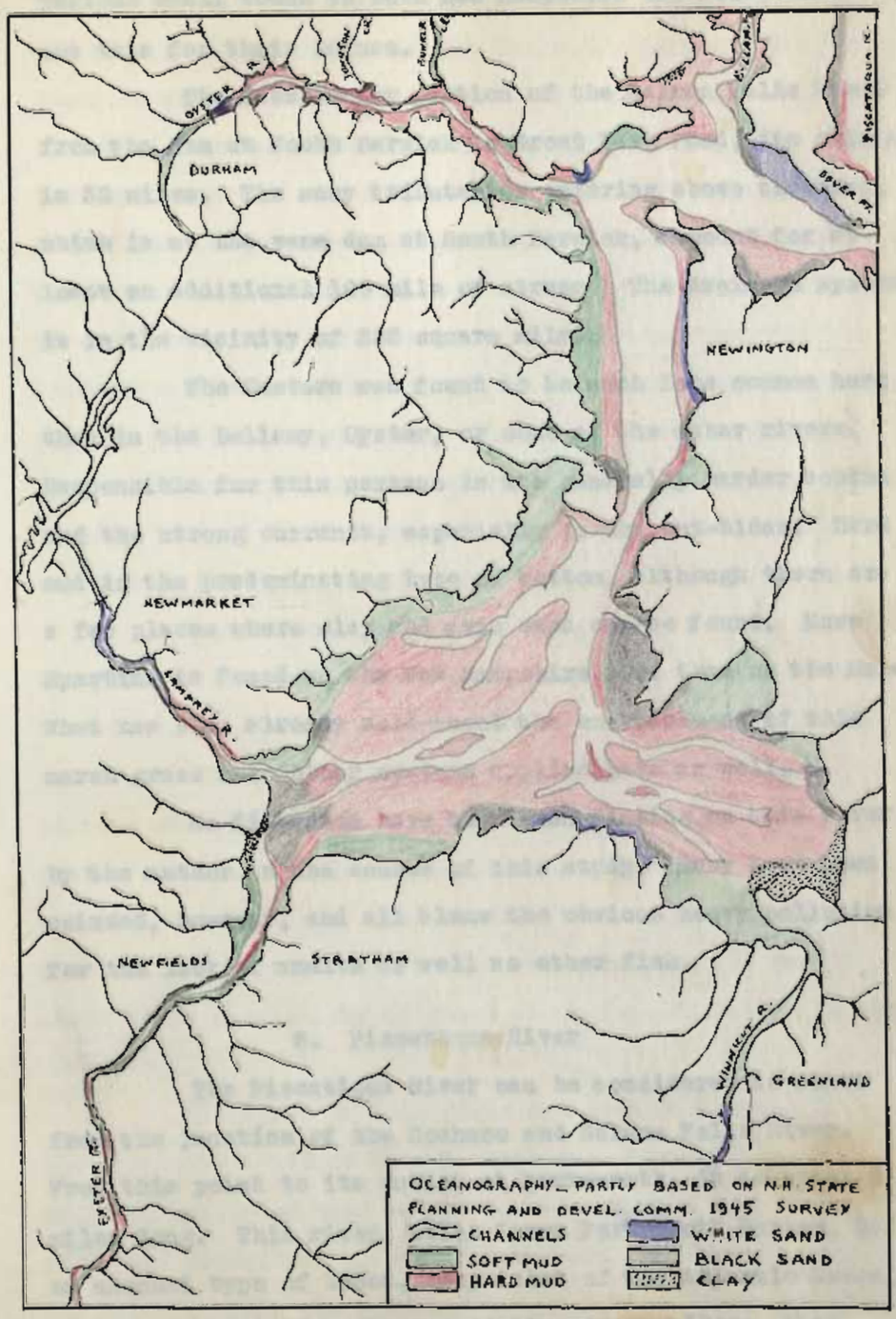
The Cocheco River can be called an open sewer. The chief sources of pollution are Dover, Rochester, and Farmington. All that has been said about the nauseaous stench, the apparent lack of higher plant and animal life at tidehead of the Bellamy River can be applied and amplified for the Cocheco. Its use from a fishery viewpoint is of course considerably limited.

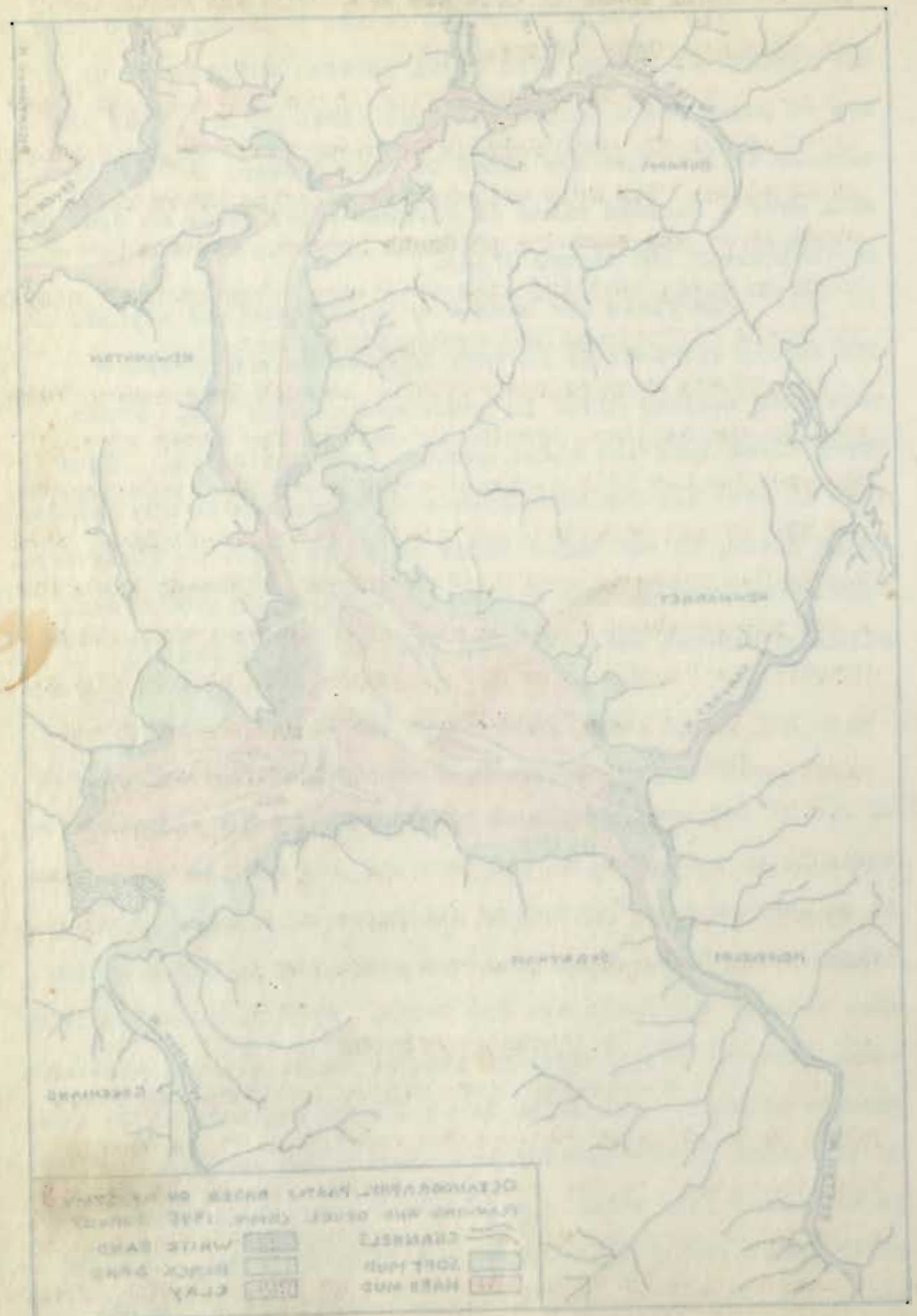
The Cocheco joins the Salmon Falls River to form the Piscataqua River. The tidal portion which backs up to the dam at Dover has a length of about three miles. When the various tributaries are added to the Cocheco, it then involves well over a hundred miles of streams which drain an area of approximately 140 square miles.

The flats are narrow in this river and outside of its strong currents it is very similar to the previous mentioned Bellamy River in practically every way. Fresh Creek flows into the tidal portion from the north. Since this is near the Cocheco River's confluence with the Salmon Falls River, it was hoped signs of smelt might be discovered. None were found in this apparently little polluted creek although several attempts were made to locate them.

7. Salmon Falls River

The Salmon Falls is still another glaring example of one of our poorly managed rivers. Years ago, history records it as being one of the best and its name is well known to be derived from the former abundance of salmon. The Salmon Falls River flows from the north and is the boundary line between New Hampshire and Maine. From the standpoint of administration any management program might present problems because of this. Pollution is as disgusting here as in some of the other rivers already mentioned. The notorious offender in this case is a Fiber plant located some miles upstream. Other industries are important contributors also. In fact there are many opportunities for pollution which include the


OYSTER R.
DURHAM
NEWINGTON
NEWMARKET
LAMPREY R.
NEWFIELDS
STRATHAM
WINNICUT R.
GREENLAND
EXETER R.
OCEANOGRAPHY_ PARTLY BASED ON N.H. STATE PLANNING AND DEVEL. COMM. 1945 SURVEY
CHANNELS
SOFT MUD
HARD MUD
WHITE SAND
BLACK SAND
CLAY



various small towns in both New Hampshire and Maine that use this for their refuse.

The fresh-water portion of the Salmon Falls River from the dam at South Berwick to Great East Pond, its origin, is 32 miles. The many tributaries entering above tidehead, which is at the same dam at South Berwick, account for at least an additional 100 mile of stream. The drainage system is in the vicinity of 325 square miles.

The Zostera was found to be much less common here than in the Bellamy, Oyster, or some of the other rivers. Responsible for this perhaps is the generally harder bottom and the strong currents, especially on the out-tides. Hard mud is the predominating type of bottom, although there are a few places where clay and even sand can be found. More Spartina is found on the New Hampshire side than on the Maine. What has been already said about the encroachment of this marsh grass onto other systems applies here as well.

No fishermen have been seen fishing on this river by the author in the course of this study. Many have been quizzed, however, and all blame the obvious heavy pollution for the lack of smelts as well as other fish.

8. Piscataqua River

The Piscatiqua River can be considered to start from the junction of the Cocheco and Salmon Falls River. From this point to its outlet at Portsmouth, it is about 8 miles long. This river, which forms Portsmouth Harbor, is an unusual type of broad, deep inlet of the Atlantic Ocean, and is notorious for its formidably strong tides. When
and is notorious for its formidably strong tides. When

the tides run, it is said, the Piscataqua becomes one of the most perilous rivers in New England. Only the Bay of Fundy is reputed to have stronger tidal currents.

Several conditions are responsible for this. The two Bays cover an area of approximately 5540 acres, and have a shoreline of 40 miles. They form a tidewater reservoir with tides as high as nine feet at times. The vast volume of water they hold must come in and go out of them via the Piscataqua River. Adding to the flow are the various rivers already mentioned coming into the Bays. These conditions, in conjunction with the tremendous depth of Portsmouth Harbor, ranging from 65 to 90 feet, are reason enough for anyone to appreciate the strong currents.

The reason for treating this river in some detail in spite of the fact smelt use it only as an avenue of transportation, is because of its relation to silt pollution in the Bays. It works in this way. Much of the silt and various other pollutant borne by the tributaries of the Piscataqua are deposited when floodtide prevails in Great and Little Bays, which are natural flood control basins. The Bays can be said to act as catch-alls with the result there is no possibility of shoal or sandbar formation in the Piscataqua.

The flats in this river are insignificant. On a low tide only a narrow belt is exposed. These flats are composed mostly of hard packed mud and black sand. A few rocks and occasional gravel is found scattered about. Zostera was noted on both the N.H. and Maine side as being scattered

in isolated patches. Spartina is confined to a narrow fringe along most of the banks.

Smelt are taken by hook and line in late summer and fall fishing, but no streams leading into the Piscataqua from the N.H. side are known to be utilized for spawning. No barriers of any kind, occur on this river.

9. Summary

By summarizing the facts so far presented pertaining to the Bay, we note, approximately 700 square miles of territory is drained, and the rivers that do this form a system of 500 miles. The total estimated population is 115,000 for this area and pollution varies according to the concentration of people.

Great Bay proper has not been treated as such under separate heading. It is an enormous tidal flat, much of which is exposed when the tide is out. These flats have numerous intricate channels only the largest of which could be shown by the map on page 20. This same map shows the nature of the bottom.

Zostera can be found only on the side sheltered from the prevailing northwesterly winds. The best development is found at the mouths of the Exeter, Lamprey, and Oyster Rivers.

In spite of the various detrimental factors causing such a sharp decline in our marine fish of Great Bay, the smelt especially are capable of a great increase by proper management. It has been already pointed out in part that

one of the limiting factors for an increase in smelt is the lack of proper or otherwise acceptable spawning grounds.

IV. THE SMELT FAMILY

The smelt, (Osmerus mordax mordax) belong to the family Osmeridae of the order Isopondyli. This is a large order containing a variety of soft-rayed fishes; which agree in a number of osteological characteristics.

The family of Osmeridae, or smelt, is very closely related to the Salmonidae. Besides being structurally akin to the salmons except in size, the other chief essential difference is in the form of the stomach. In the smelt the stomach is a blind sac with the two openings close together and usually a lack of pyloric openings. In all the Salmonidae the stomach is siphon-shaped and around the pylorus many pyloric caeca are found.

All the species of smelt are small in size and most of them stick strictly to the sea, although a few go up the rivers to spawn. Some smelt have become land-locked in lakes. Smelt from two lakes in Maine were long ago (1780) described and named as specifically different from the marine smelt and also from the fresh-water smelt from another Maine lake. It has been suggested that there may be many distinct species that have been land-locked in the various fresh-water lakes. In spite of the many hundreds of smelt that have been analyzed from various waters to ascertain if there were distinct species, most authorities now generally accept fresh and salt-water smelts as essentially the same species.

Most of the smelt are confined to the north temperate

zone. All of the abundant species are edible. Commercial importance can be attached to them both directly, as food for man, and indirectly as part of the food chain of the larger fish of commerce. David Starr Jordan, has written (1905) "All furnish excellent food, the flesh being extremely delicate and often charged with a fragrant oil easy of digestion". It is little wonder then that Samuels (1904) should about the same time write: "Second cousin to the grayling and trout and one of the neatest, most graceful, and delicate of all our food fishes, is that universal favorite the smelt". To us in New England especially, we need not be sold on the merits of the smelt for most of us recognize the fine fish it is from personal experience.

The genera of the smelt family (Osmeridae) according to Jordan's latest "Checklist of the Fishes" (1928) are as follows: The best known and perhaps the most important genus is Osmerus, the smelts. There are several species of this although opinions vary concerning the number. Whatever the number, they are all very closely related and difficult to seperate. The principal Atlantic coast smelt is O. mordax mordax. The latest arrangement for the Pacific coast leave O. dentex dentex as the only species of this genus for that area.

Also in the Osmeridae according to Jordan are Mallotus (capelin) one species; Thaleichthys (eulachon) one species; and two or more species of Hypemesus which are known as surf-smelts. Thaleichthys and Hypomesus are peculiar to

the Pacific. The Osmerus and Mallotus are also found on the Pacific but are likewise common to the Atlantic and Arctic.

1. The Great Bay Marine Smelt

The fish considered in this paper and at the present time found in the waters of Great Bay is the common smelt, Osmerus mordax mordax (Mitchill). This is the same well known smelt of the inland waters of New Hampshire which has either been "land-locked" or artificially stocked.

With many species of fish there is some lack of agreement on nomenclature. This is not so with this species. Mordax, the specific name meaning "biting", was designated by Mitchill in the year 1815. Jordan and Evermann (1896) in their somewhat time worn but classic Bulletin #47, "The Fishes of North and Middle America", characterized O. mordax mordax as follows:

> "Head 4; depth 6½. D. 10; A. 15; P. 13; scales 68. Body rather long and slender; head large, with large mouth and stronger teeth than in the other species of the genus. Small teeth along the edge of the maxillary; strong fang-like teeth on tongue and front of vomer; cardiform teeth on palatines, pterygoids, and hyoid bone; mandible with moderate teeth, its tip projecting. Maxillary extending to or a little beyond middle of eye. Scales deciduous. Dorsal fins moderate, none reaching the next behind it. Gill rakers 2/3 diameter of eye. Transparent greenish above, silvery on sides; body and fins with some dark punctulations."

The color of the smelt is dark greenish above and speckled with many small black dots. Backs are known to vary at times to a lighter transparent olive green. Some veteran fishermen on Great Bay claim the fish with the darker colored backs are the sea-run of fish that have just come into the

Bay in contrast to the lighter colored ones that are in all the time, or else the sea-run that have "bleached out" after a short while in brackish water. No grounds can be found to substantiate this. In the course of this work this color difference has been an apparently normal variation. The sides show a paler cast with a broad longitudinal silvery band. Below the silvery band, the color is a light translucent green fading into silver on the underside.

Another small slender fish, the silverside (Menidia notata) is common to the Bay, and has a similar color pattern. Since the silverside has two large spinous dorsal fins it should not be confused with the smelt which has a small but discernible adipose fin. At this time it may be noted the author has found fishermen at times taking these silversides in their weirs, but erroneously calling them capelin, (Mallotus villosus). There is no record of any capelin having been taken out of the Great Bay.

The range of smelt as given by Jordan and Evermann (1896) is our Atlantic Coast of the United States from Virginia northward to the Gulf of St. Lawrence. According to Bigelow (1924) the occurrence in the Gulf of Maine and general distribution is as follows:

> "Familiar around the entire coast line of the Gulf of Maine, but varies greatly in abundance from place to place according to the accessibility of streams suitable for spawning, from which it seldom wanders far alongshore. Smelt are still very abundant all around the inner parts of Massachusetts Bay and its tributary harbors, though many of the local streams are barred from them now; thence northward and eastward, too, along the coast of Maine. Smelt

are also found generally along both the New Brunswick and the Nova Scotian shores of the Bay of Fundy, but to judge from Canadian fishery statistics they are far more plentiful near the mouth of the bay and on the Nova Scotian side than anywhere on the New Brunswick shore or farther up the bay, where only a few hundred pounds are caught annually. Smelt are also plentiful on the west coast of Nova Scotia, facing the open Gulf, as is reflected in a catch of almost 58,000 pounds for Yarmouth county in 1916-17".

The Great Bay smelt have a definite, peculiar "cucumber smell" especially noticable right after having been taken out of the water. Several printed accounts substantiate this odor. Bigelow (1924) disagrees on this point and in part states: "Smelt fishermen often speak of a trace of this (odor) but it is so faint that I have never noticed it though I have caught and handled many." In a footnote Bigelow also writes: "The European smelt (O. eperlanus) smells so strong that it is not held in very high esteen." In spite of the odor of our smelt, which is more noticable to some than to others, no one has yet been heard to complain or even incriminate any degree of offensiveness.

2. Distribution in the Bay

Formally smelt were one of the most abundant fishes in the Great Bay area. They were taken from every river and inlet in large quantities. Records are known where up to one hundred pounds have been taken through the ice on hook and line during one tide by one fisherman. Large catches were common to all areas, even those where this season (1948-49) not a single smelt is known to have been caught.

Greenland Bay, the Exeter and the Lamprey River seem to be the waters most frequented by this fish. The Oyster River until three years ago likewise was the scene of a much better run than experienced this year. Now this same river has had only about fifteen pounds taken through the ice via the bownet method. The earliest and only record of smelt being caught by hook and line in the Oyster River for this season was on October 12, 1948. Two fishermen fishing for tomcod (Microcadus tomcod) had taken two smelt of the two and one half old age class at the mouth of Beard's Creek in Durham.

The Bellamy, Cocheco, and Salmon Falls Rivers with their various tidal tributaries were periodicslly checked for smelt. None are known to have been taken out of any of these waters during the 1948-49 fishing season. The methods employed in determining this lack of fish include setting of nets, checking the autumn season pole fishermen from bridges, wharves and shore, noting the lack of a single bob house on the ice, the general lack of a spawning run of smelt, interviews with the natives and the conservation officers.

Our current laws regulating the salt water smelt fishery close the season from April twentieth to July first. Little is known of their movement during this period. Smelt fry has been taken during this period from time to time in the Bay. A record for a mature smelt is known from a striped bass (Roccus saxatilis) that was caught while trolling in Little Bay near Fox Point in June of 1948. Mr. Ralph Garland,

proprietor of a Sporting Goods Store in Newington, N.H. furnishes this interesting record. Several other fishermen confirmed this fish being a smelt. The striped bass had not wholly swallowed the smelt at the time it was caught on an artificial lure and when brought to gaff, it was found lodged in the gullet. Six inches is the length given for this smelt.

Very little fishing is done during July and August for smelt. Those who fish during this summer period do not bother to fish Great Bay proper but rather the waters of the Piscataqua River outlet to the Atlantic. If smelt are in this region, they can usually be had in Sagamore Creek in Portsmouth and Seaveys Creek in Rye.

Much more work must be done in Great Bay to determine more exactly the smelt population and movements. Little is known of the life of the smelt in the sea. We know that they will move into sheltered bays and inland stretches of salt and brackish water like our Great Bay in autumn and early winter. Smelt continually move within these areas. Just how much movement there is between sheltered areas and the ocean is not known.

The following are more records for smelt as they appeared in various parts of the Great Bay. The October 12, 1948 record for Beards Creek entering the Oyster River has already been given. On November 6, 1948, smelt were seen jumping out of the waters south of Adams Point in Durham. Three smelt, about five inches long, were taken in Crommets

Creek in Durham on November 8, 1948. Goodrum (1941) writes:

> "In the fall of 1939 one smelt was obtained in the weirs in the Oyster River as early as November 19th. A week, later November 26th, the run of smelt really began when half a dozen of these fish, six to nine inches, were obtained. During the next four days several smelt were taken. After this none were obtained, and the weirs were dismantled of their netting on December 25th".

On November 23, 1948 smelt were seen jumping north of Vols Island in Newmarket. Again on November 27, 1948, two smelt seven inches long were taken out of Crommets Creek. Many others were observed breaking water in the area of this creek where the dirt road crosses. A careful check disclosed smelt were playing all along the shore of Great Bay from the bridge over Crommet Creek to about a mile south of Shackford Point in Newmarket.

The winter of 1948-49 will go on record as being exceptionally mild and open with little ice forming and not staying long. It was not until February 6, 1949 that the ice was sufficiently thick on Greenland Bay to allow fishermen upon part of it. Many waited for this and came en mass. Over 150 holes were fished without a single smelt being landed. Only a single day provided fishing that amounted to any smelt being taken through the ice. On February 12, 1949 the run was unusually heavy with at least three fishermen weighing in 50 pound catches by hook and line. The next day over 60 bob-houses were counted on the ice where on the day previous 22 houses were seen. Over a hundred people fished, some from early morning to late afternoon with the largest catch being six fish. This large movement of smelt that showed up this one day never reappeared.

S. Size

The lengths of the total population checked for this paper ranged from 55 to 274 millimeters. (All measurements given are in total length, i.e. the distance from the snout to the tip of the caudal fin.) This 274 mm. (10.76 inches) female smelt weighed 120.15 grams and represents the largest fish taken in the entire survey. Mr. John Argeresw of Portsmouth, N.H. caught this fine five and one half year old specimen with hook and line on October 9, 1948 in Sagamore Creek while on a fishing expedition with the author.

Kendall (1926) has the following to say about size of smelt:

> "The American smelt is known sometimes to attain a length of 13 to 14 inches, although such size are not common, and smelts from 10 to 12 inches long are regarded as exceptionally large fish. The average length of smelts selected for their large size probably would not exceed 9 to 10 inches. The general average of the most common smelt may be inferred from the following: Fish obtained in the Washington marked in December and said to have come from Portland, Me., averaged six to the pound, ranged from 7.5 to 8.75 inches in length, and ranged in length from 6 to 8 inches, averaging about 7.14 inches."

Jordan and Evermann (1896) cite as maximun length being twelve inches. Bigelow and Welsh (1924)-state:

> "Smelt grow to a maximum length of about 13 or 14 inches, few larger than a foot long are seen, however, the adults run only about 7 to 9 inches. According to size and fatness smelt weigh from 1 to 6 ounces"

Warfel, Frost and Jones (1942) in their paper on smelt of Great Bay have a size range from 69 to 230 millimeters, with a total of 287 individuals studied. The following

figures represent the size of the smelt as obtained from on the spot measurements on Greenland Bay from people fishing through the ice. February 12, 13, and 15, 1949 proved to be the best fishing days and a random sampling for length of these fish, with females predominating, is as follows:

Total length in millimeters	Number of individuals	Total length in millimeters	Number of individuals
110	1	190	32
115	1	195	1
140	3	200	24
145	5	205	3
150	4	210	23
155	3	215	3
160	15	220	16
165	19	225	3
170	24	230	7
175	12	235	2
180	22	240	3
185	8	245	2

A similar set of figures can also be given for the length of smelt that were taken as random samples from the weirs of the Lamprey and Exeter River over a period from March 17 to April 15, 1949. All these measurements are of fish as they were just taken out of the weirs and not after the larger or better marketable sizes had been removed from the catch.

Figure 1 shows this distribution into 28 size groups in multiples of five. It was determined in the field that measurements to the nearest fifth millimeter worked out best for all practical purposes. The number of individuals is plotted on the ordinate while the millimeter frequencies of total length are shown on the abscissa. The red line represents female and the blue that of male distributions.

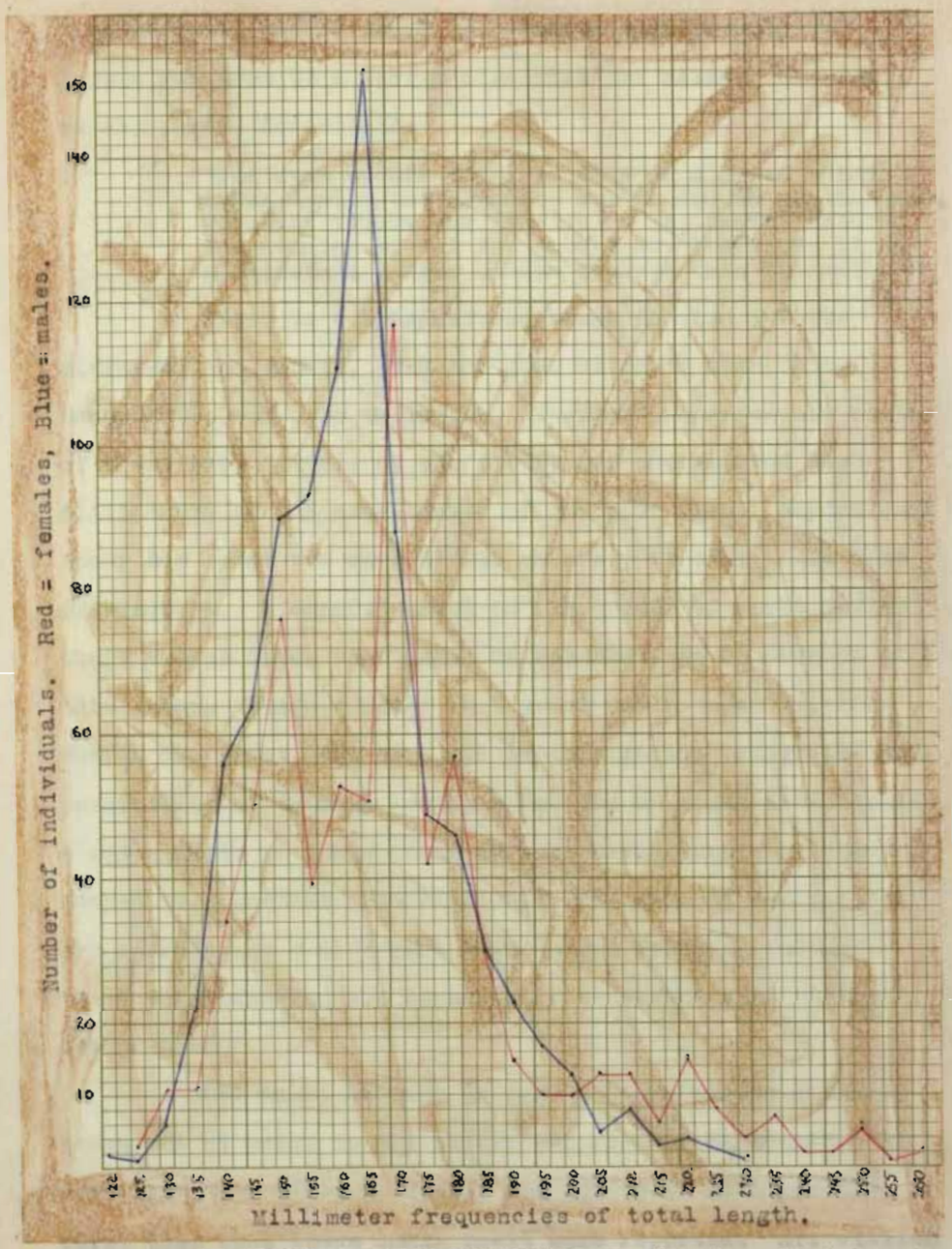


Figure 1. Distribution of random sample of smelt taken in weirs in the Exeter and Lamprey Rivers from March 17 to April 15, 1949.

From graph it can be noted the females consistantly run larger and grow to a larger size than the males. Warefel, et al; (1942) determined:

> "The mean of the total lengths of all the males taken during the spawning run is 150.25 millimeters. The same figure for females is 161.3 millimeters. The females of all age groups are therefore 11.05 millimeters larger on the average than the males."

There is a considerable range in size for the different age groups. The one year class is used as an example to show this variation. Previous study on the smelt of Great Bay, Warfel, et al, (1942) has established 86.0 millimeters as the mean length of one year fish. Our current study has shown the mean length of one year olds to be 74.20 millimeters. A careful check on the growth of smelt during their entire first year would be necessary to be certain of this group. These smaller than usual smelt to be expected during the first part of April in this region brings up the possibility of perhaps having a new run of smelt established; a run similar to those found in some fresh waters of New Hampshire. Another possibility is that some of our smelt are spawning at a different than normal period. Both of these possibilities are theories to be worked upon at some future time.

The smelt lengths in figure 2 are random samples taken out of weirs in the Exeter and Lamprey Rivers during the first week of April 1949. The spring of 1948 was the first time that these small smelt were reported. Mr. William Watson, weir fisherman on the Lamprey River, was the first to notice them in his weirs. This was also the first time

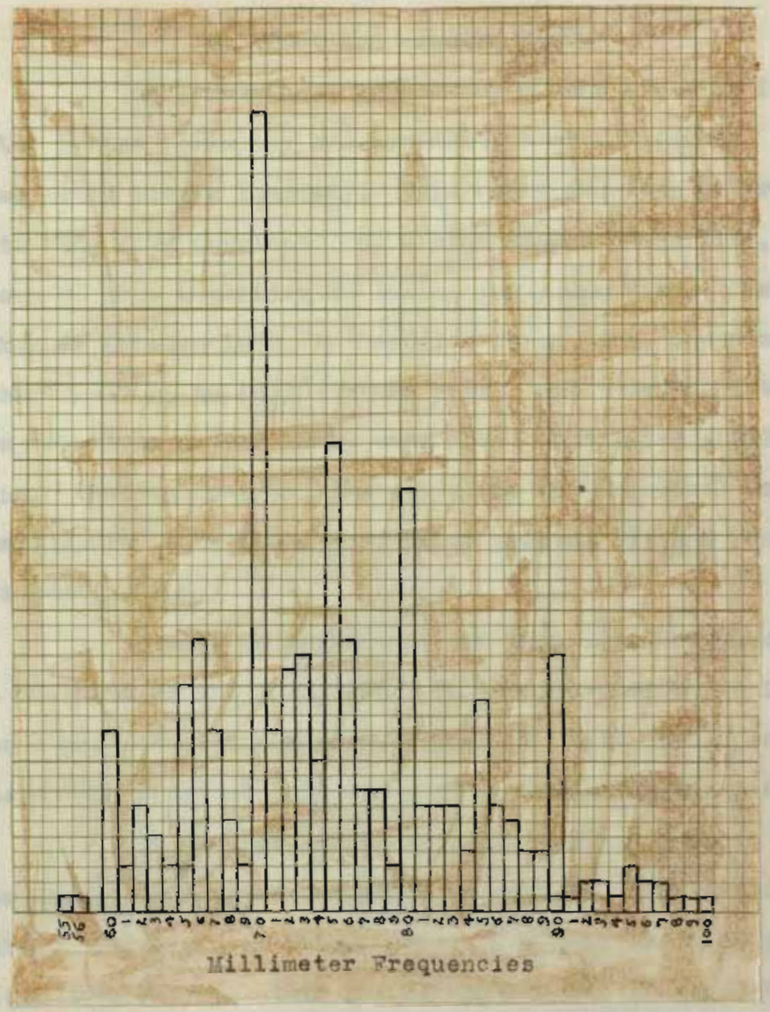


Figure 2. Size range of random sample of small smelt taken from the Lamprey and Exeter Rivers during the first week of April 1949. Each square equals one smelt.

in his long career on that river that he has seen smelt of this size in April.

4. Food and Feeding Habits

The carnivorous propensity of the smelt is indicated by the character and arrangement of its teeth. Its name means biting (mordax). This voracious fish of prey, with body form developed for a high degree of agility, is known to show a particular liking for young fish. Smelt taken in October 1948, in Seavey's Creek, Rye, contained other smelt up to half its own size. Smelt taken in the Lamprey River in May 1949, were found containing small herring. Various European workers claim the principal food of their smelt to be fish, especially herring fry and young of its own species.

It must be remembered the food will vary according to the size of the fish, which follows, according to its age. The close-set gill rakers show that at least in the early stages of its growth, it can utilize rather minute plankton.

The smaller smelt taken on hook and line in the New Castle, N.H. area and parts of the Bay, were found to subsist largely upon Entomostraca, the copepod forms predominated with various other larger types mixed in such as Palaemonetes and to a less extent Crago.

Plankton in the Great Bay area is abundant. In all the tows made, both phytoplankton and zooplankton were taken in great quantities. Nekton was also taken in abundance. This is of vital importance not only to the smelt, but to all

the other fish as well since they are directly dependent on this fish food-cycle. Of the Zooplankton, Calanoid copepods are the dominant forms together with their many nauplii. Murphy (1944) reported Acartia tonsa to be the most abundant copepod in Great Bay. She also lists 17 other forms as present with their various degree of abundance. Our primary concern with plankton is its relation to the food-cycle which in Great Bay is more than ample to support the present fish population and could stand an even much larger population.

From observations and dissections, it is indicated the larger individuals subsist largely on crusteceans and various small fish. Various shrimps and shrimp-like forms are used quite extensively. The common shrimp (Palaemonetes) was found in smelt of all sizes. This incidently makes the best bait for taking of smelt until the weather gets to the freezing point at which time these shrimp take to the mud. The annelid commonly called clam worm (Neris virens) is the favorite bait for fishing through the ice. Mummichogs (Fundulus heteroclitus) and silversides (Menidia notata) have also been found in smelt and are likewise known to make good bait.

It was noted that smelt taken during the night in October 1948, had from little to no food in their stomachs but the intestine contained bits of crustacean and unidentifiable refuse.

Smelt feed readily while in the Bay, but as soon as the ice leaves and the spawning run into the rivers start,

they seem to stop feeding. Many smelt have been opened to check for stomach contents. Very little to no feed was found in any smelt taken in the weirs and it is the weirs that take advantage of the spawning run. However, once the fish had shot all its spawn or even with some traces of spawn remaining, it was noted they again began to feed heavily. Smelt dissected on April 15, 1949 were found to have their stomachs distended with shrimps (Palaemonetes) and small killifishes (Fundulus).

5. Sex Predominance

The smelt caught with hook and line at the mouth of the Piscataqua River, and those taken through the ice in the Bay, were not particularly watched for sex since they did not represent breeding fish. From rough notes, it can be noted however that for the smelt taken by pole fishing the sexes ran about equal while most of the fish pulled through the ice were females. The sex ratio of the populations varied considerably when sampled but a definite trend can nevertheless be established in this connection. Of the 1445 smelt taken during the period between March 17, to April 15, 1949; from weirs in the Exeter and Lamprey Rivers, 906 were males and 539 were females. This gives a male/female ratio of 1.709. In any one sample the ratio of males/females ran as indicated in table 1.

It is apparent from the table that the males predominated practically throughout the entire run except toward the end where females held their own or else predomi-

Date of collection (1949)	Exeter or Lamprey R.	Number of Fish	Number of Males	Number of Females	Ratio M/F
March 17	E	40	23	17	1.353
" 18	E	46	36	10	3.600
" 22	E	41	24	17	1.411
" 24	E	181	129	52	2.288
" 26	E	114	50	64	0.781
" 30	E	172	85	87	0.977
" 30	L	82	49	33	1.485
April 1	L	132	102	30	3.400
" 2	E	204	145	59	2.459
" 2	L	287	187	100	1.870
" 4	L	65	44	21	2.095
" 15	E	42	21	21	1.00
" 15	L	39	11	28	0.392
Totals		1445	906	539	1.709

Table 1. Sex ratio of Great Bay Smelt.

nated. All fish in samples indicated under 100 individuals, represent the entire catch of the weir for a single tide. For example, the April 15th take (one tide) for the Lamprey River was 39 smelt consisting of 11 males and 28 females.

Stragglers taken during the first part of May 1949 proved to be mostly males. Four smelt taken in the Lamprey River on May 2, 1949 were males. The next day eight males to four females were taken in the same river. Alewive fishermen on the rivers claim many more males during the end of the spawning run.

Dimorphism should be considered with the sex problem. Langlois (1935) cites three factors which enabled him to distinguish sexes: (1) Color, the males being darker; (2) size, the female being larger; and (3) pronounced nuptial tubercles on the males.

6. Spawning Season and Habits

The smelt is a migratory fish like the salmon, though not to such a high degree. It moves from salt, to brackish waters of our sheltered Bay months before actually spawning. Being anadromous, they eventually seek fresh water for depositing the eggs. Autumn and early winter is known to be the time when the majority enter the Bay. At this time they are constantly roving. Since our smelt population is down to such a dangerously low point, it is obvious why over 150 holes fished through the ice on Greenland Bay failed to land a single smelt. The schools are so small and few, that none apparently happened to pass this large acerage over

which the fishermen were spread. Normally, as in years past, immense quantities are taken by hook and line and in nets as they wander about.

It has been proved that smelt will return for spawning to the original stream in which they were spawned or hatched from eggs planted. Therefore, it is possible to have a stream or portion of the Bay well stocked in contrast to other areas with conditions not suitable and as a result smelt entirely depleted.

Coastal Warden Orin A. Arlin of Byfield, Mass., has kindly consented for his unpublished material pertaining to artificially creating spawning runs to be used by this writer. Mr. Arlin has done commendable work in improving the smelt fishery on the Parker River located in Newbury, Mass. We have in him a vindicator of the smelt parent stream theory. Cart Creek flowing into the Parker River had not supported a spawning run of smelt for years because of silt and mud pollution. This was cleaned up. Silt and mud was taken out by hand, spawning beds prepared, smelt eggs introduced and four years later an excellent spawning run was established. Similar work has been done on other streams in his area. Concerning the above matter we can cite Jackson (1949).

> "In this connection it should be borne in mind that beyond a doubt smelt return to the stream in which they were originally spawned for spawning."

As spawning time approaches there is an urge to seek fresh water. Smelt in passing from salt to brackish, then to fresh water must acclimate themselves to changes in

salinity. They do this in part by working up and down the rivers with the tides. Other contributing factors causing this constant moving about are feeding habits and the very nature of the fish. The weirs at this spawning period take out much of the smelt that should be allowed to spawn. The part that weirs have played in depleting the smelt of Great Bay by taking the spawning fish has been bitterly disputed. The current State regulations pertaining to the taking of marine smelt should be modified to provide better protection. Jackson (1944) states:

> "If a fish is not taken by the weirs on its way upstream it almost surely will be when it starts back to waters of greater salinity."

Smelt spawn was found in only two places in the Bay area, at the tideheads of the Lamprey and Exeter Rivers. Figure 3 shows the Lamprey River smelt spawning area in Newmarket. As poor as the spawning run experienced, more eggs were found here than elsewhere. All the other possible areas for spawning were checked but nothing found. In this respect, the Winnicut and Oyster Rivers should be singled out as potentially two of the best spawning areas. Many of the smaller brooks seem well suited for spawning-runs. These same brooks that do not support any smelt, have good alewife spawning runs. The following brooks should support smelt and it is believed artificial planting of eggs would create a population that would come back: Peverly and two unnamed brooks in Newington; Pickering, Packers; and Bracket Brooks plus the Winnicut River in Greenland; most of the smaller

Figure 3. The Lamprey River smelt spawning area in Newmarket, New Hampshire. Photo shows part of what can be considered the currently best spawning area in Great Bay.

brooks that flow into the Exeter River; Crommet and Johnson Creeks in Durham.

Some of the best late ice fishing is had at the mouth of the Winnicut River. Yet, not a single smelt is known to spawn in that area which seems so well suited. This river has been compared by Massachusetts Fisheries experts to their Essex River which supports a fine smelt fishery but where none are known to spawn. In neither river has the introduction of eggs been tried to date.

On March 29, 1949, the first spawn of the season was located below the Newmarket dam in the Lamprey River. This initial spawning took place at a water temperature of 49°F. This temperature may seem high compared to the generally assumed optimum temperature of between 40°and 42°F. A considerable variation has been found to exist in the temperature at which smelt will begin to shoot their spawn. This year in the Parker River, the spawning run was well underway by the 4th of March when the water temperature was only 30°F. Dr. R.A. Mckenzie of the Fisheries Research Board of Canada Atlantic Biological Station writes in a letter:

> "Usually our smelt enter the brooks and begin spawning between 43.7°and 46.4°F." (This is for the Miramichi River system in New Brunswick where 1/3 of the Canadian smelt catch originates.)

Temperature records of the water were kept from February 24th to April 22nd, 1949. Figure 4 covers the period from February 28 to April 13, 1949. The graph represents the mean temperature of daily reading taken at six stations as follows: 1. Piscataqua River at General Sullivan Bridge; 2.

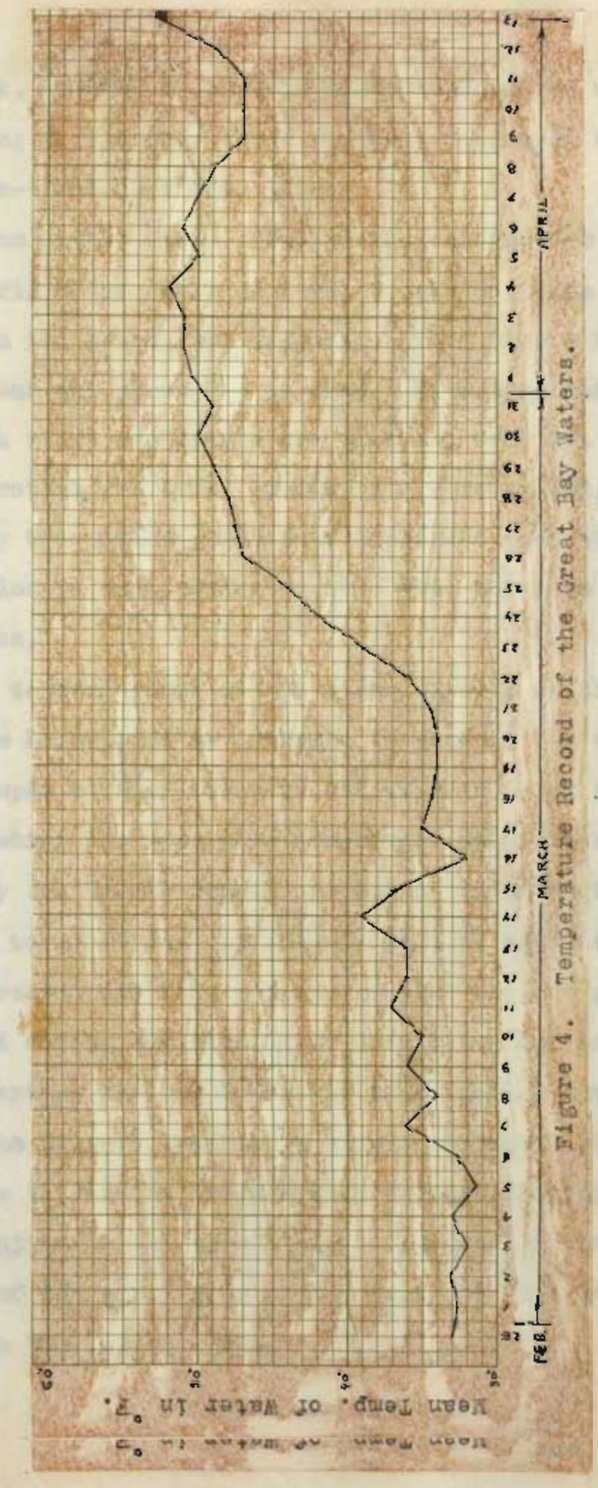


Figure 4. Temperature Record of the Great Bay Waters.

Bunker Creek, Durham; 3. Johnson Creek, Durham; 4. Oyster River at dam; 5. Lamprey River at dam; 6.unnamed brook on Newington--Greenland town line.

The Exeter River tidehead was checked for smelt spawn on April 2 and again on April 6 with negative results. On April 9th the search was repeated. This time a few eggs were found but all proved to be dead. Nine eggs were counted on one brick which represents the greatest density. The water temperature was 46°F. These eggs were killed, it is believed, by the potent pollutents discarded from the Exeter Mills. Follow up examination of this area for more spawn was fruitless.

A careful count of the spawn already mentioned found in the Lamprey River averaged 72 eggs to the square inch. A sample of four ordinary bricks were taken from the channel to which the eggs were adhering. Each brick averaged 1022 eggs by individual count. Repeated visits to the same area failed to prove any appreciable gain in eggs deposited. A possible reason for this perhaps is that the dam gate was being closed during the evening to save water for power purposes starting the day following this initial spawning.

The largest smelt have always attracted attention. Females were by far the largest fish in the spawning run. It was definitely noted that these large females were in the first half of the run. None of the four and five year olds were seen in the latter part.

After spawning the smelt are suspected of returning to salt water. Concerning this Bigelow and Welsh (1924) write:

> "The adult smelts return to salt water immediately after spawning, to spend the summer either in the estuary into which the stream in which they spawn empties or in the sea close by. On the Massachusetts coast north of Cape Cod all the spent fish have left fresh water by the middle of May, in some years earlier. On the Maine coast, too, a good proportion of the spent fish are in salt water by the first week in May."

From the Parker River in Massachusetts we have reliably reported the spawning run was two weeks earlier than usual this year. By March the 4th the run was heavy and lasted about a month. After April the 6th no smelt could be found.

On the Lamprey River a few females loaded with spawn were still present as late as May 3rd. On this date four females taken out of the weir shot most of their eggs when gently handled for examination. At the same time eight males on examination disclosed that all but a trace of milt was expelled.

7. Early Life History

Information on the early life history of the smelt in Great Bay is fragmentary. Professor Jackson of the University of N.H. reports from notes that smelt fry was available in large numbers in 1942. In the years that followed, the decrease has been steady up to the present time. Many hauls with plankton nets failed to capture any smelt fry. These hauls were made during the month of April

1949 in such places as Crommet Creek, Exeter River, Lamprey River and parts of the Oyster River.

The eggs of the Great Bay smelt averaged about one millimeter in diameter. All the spawn found was adhering to hard clean surfaces, such as rocks, rubble, bricks and gravel. The peculiar manner of attachment should be noted. After extrusion, a portion of the surrounding membrane of the egg breaks away and becomes turned back but remains attached at one point. By this turned back membrane the egg is held in place against the current. As soon as the smelt are hatched, they are swept downstream. Unfortunately the writer has not found the time to study these delicate transparent larvae.

The young are subjected to all sorts of dangers and comparatively few must survive to attain the adult age. In spite of the adversities they encounter their rapid migration is necessary for survival. The place of birth usually does not afford the necessary quantity of suitable food which is to be found in only more open or tidal waters.

Figure 5 is from Ehrenbaum (1894) on the smelts of Elbe River and was copied from a plate in Kendall (1926). Observations by Ehrenbaum (1894) showed that newly hatched fry were 5 to 6 millimeters (about 1/5 to nearly 1/4 inch). In one month they grew from a little over 0.55 to 0.7 of an inch in length. In three months they reached 1.25 to 1.45 inches. At five months the lengths were found to range from 1.73 to 2.36 inches. It was also determined that the smallest mature smelt was about four inches long and two years of

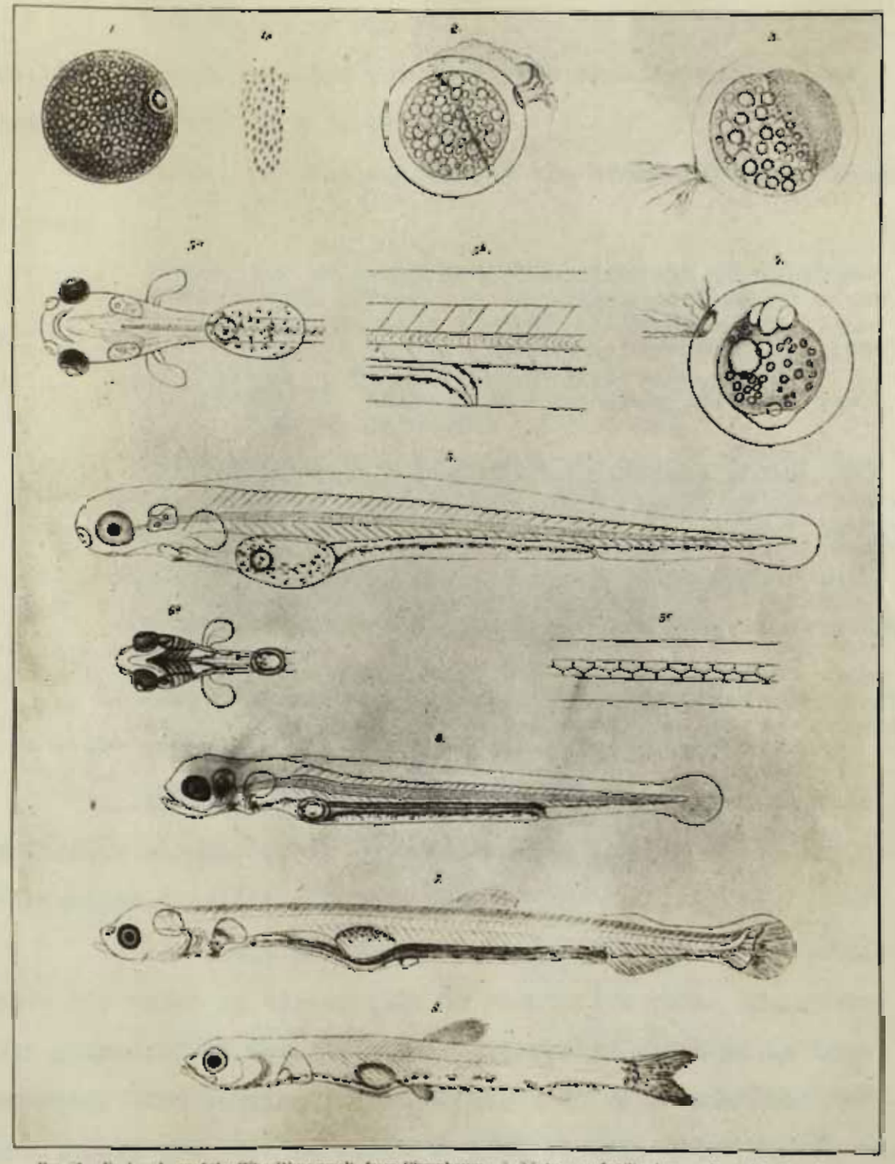


FIG. 5.—Embryology of the Elbe River smelt, from Ehrenbaum. 1. Mature, unfertilized egg, collected before absorption of water. Diameter 0.75 millimeter. 1*p*. The pores of the *zona radiata externa* of the egg greatly magnified. 2. Mature egg immediately after placing in water containing sperm; the *zona radiata externa* is ruptured and on the point of turning back on itself, whereby it remains only near the micropile, suspending the egg. 3. Egg with developed (yellowish) transparent yolk, 6 hours after fertilization. Diameter 0.90 millimeter. 4. Egg with embryo of 9 days; large yolk and few oil globules. 5. Smelt larva immediately after hatching on April 19. Length 5.5 millimeters. 5*a*. Showing underview of anterior portion of the same larva with its inferior mouth and extended pectoral fins. 5*b*. Posterior portion of same larva greatly magnified, also the corda cells. 5*c*. Underview of the corda of the same larva. 6. Smelt larva of April 24, 6 days old. Length 6.3 millimeters. 6*a*. Anterior portion of the same larva. 7. Larva of May 27, 15.5 millimeters long. 8. Larva of June 17, 28 millimeters long

age, but many larger fish were found to be immature.

The growth of the smelt from the fry stage is rapid, although the size for any given time is variable as indicated by figure 2 on page 37.

Kendall (1926) concerning the growth of young smelt states:

> "Smelt fry obtained from the stomachs of sticklebacks (Gasterosteus) in the tidal portion of Casco Bay, Me. creek, only a short distance below high-water mark, on May 13, averaged less than 0.2 inch in length. Judging from the presence, in some instances, of incompletely absorbed yolk sac the fish could not have been hatched long.
>
> On August 3 translucent young smelts, ranging in size from 1.2 to 2 inches, were caught at an island in Casco Bay several miles from any possible breeding place. On October 14 young smelts, still translucent caught in the same bay, ranged from about 2 to 2.55 inches in length. On December 11 others, also translucent, ranged from 2.4 to 3.6 inches long.
>
> Again, on the following February 10, similar young smelts ranged from about 2.8 to 3.6 inches in length. Still again, on March 5 following, specimens ranged from 2.4 to about 3.75 inches in length."

Young smelt can be easily confused with the other extremely slender forms such as herring (Clupea harengus), silverside (Menidia notata); etc.

The smelt can always be distinguished by the adipose fin which is discernable in about five weeks of growth. For younger fish the vent is well foreward compared to the herring. The herring fry which has been often mistaken for smelt have the vent so far back that it lies close to the base of the tail.

8. Age and Rate of Growth

Hundreds of smelt were studied to determine their age both by the scale method and by measuring for length. The marked scarcity of small adult smelts was found to be alarming. Not even a dozen of the fish taken through the ice were of the two year old size. Comparatively, there were many smelt of the larger sizes. Many fishermen declared, in amazement, the fish taken this season as the finest for size and that the Bay had not produced such a run in many years.

Such a condition of large size fish predominating may be fine from the point of view of the fisherman, but bad in the eyes of the biologist. Absence of these smaller adult fish indicates a poor breeding season two years ago. Lack of the former abundance of smelt indicates poor breeding in general. Combined with our current poor breeding season, time alone will demonstrate what man can reap in the future. The occurrence of larger fish is only the normal survival of old fish that have increased in size in spite of the many vicissitudes.

Examination of figures for fish taken through the ice show the three and four year olds running almost even but with slightly more four year old fish. The predominating four year old class averaged 220.0 millimeters in length. A surprising fact is that almost as many five year old individuals were present as the one year group. The largest fish

taken in the survey was the female measuring 274.0 millimeters. (weight 120.15 grams), but need not concern us here especially, since it was caught in Sagamore Creek. This fish was aged at five and one half years old on October 9, 1948.

In 1942 Warfel et al, from a study of scales of Great Bay smelt, determined that fish 1 year old averaged 86.0 millimeters, 2 year old 144.9 millimeters, 3 year old 171.0 millimeters, and the few individuals in the 4 year group 220.0 millimeters. Elsewhere we have stated our 1 year old smelt encountered this season averaged 74.0 millimeters. The five year old class averaged 240.0 millimeters in length and is based on 20 individuals taken out of weirs in course of random sampling of all age groups.

Egg counts were made for all age groups, i.e. for the 2,3,4, and 5 year old females. All fish used for these purposes were carefully chosen for representative size, and carefully handled so as not to expell any spawn before it could be counted. For all age groups a gram weight of spawn averaged 2010 eggs. For the purpose of this egg counting, a gram of spawn for each age group was counted before the egg totals were computed. For fish taken on succeeding days, a gram of spawn was again weighed and counted to be relatively certain our base for computation had not changed. Table 2 shows the number of eggs each age produced.

9. Predation and Parasites.

Various species of fish were found to be peradators of smelt and their eggs. As for parasites, one nematode seemed

Age	Number of Females	Averaged No. of eggs (in thousands)	Egg range (in thousands)
2	53	6.1	2.5 to 11.6
3	55	16.1	9.7 to 24.2
4	16	28.2	18.5 to 39.1
5	15	50.9	40.0 to 69.1

Table 2. The Great Bay smelt egg counts according to age groups. Smelt mature in two years.

to predominate. Very little has been published concerning so-called enemies of smelt, although presumably there must be many.

The distinction of heading the list of enemies is man. It has been stated man is the only enemy smelt need fear, for he is the great disturber of balances. Man in the past and presently is to a great extent the most wanton and selfish destroyer of not only smelt but also anything else that is the object of his own pursuit.

Many specimens of tomcod (Microgadus tomcod) were examined. All sizes were found to feed on smelt and also the eggs. Tomcod can be considered to be the most conspicuous predator encountered in the Bay. It was not unual to find these fish of the 300 millimeter size distented with smelt that measured 150 millimeters in length. All during the stay of smelt in the Bay, tomcod were found associated with them. Fishermen through the ice have taken as many of these fish as they have smelts on some days. During the weir fishing period, often more tomcods then smelt were netted.

The smooth-flounders (Liosetta putnami) were found with smelt eggs in their stomachs. Although no winter-flounders (Pseudopleuronectes americanus) were found with ingested eggs, primarily because most were taken before the smelt spawned, they do occur in the Bay and should be considered along with the smooth-flounder. Four-spined sticklebacks (Apeltes quadracus) and the common silversides (Monidia notata) were also found to be distended with smelt eggs.

A record of striped bass (Roccus lineatus) feeding on mature smelt is given elsewhere. Eels (Anguilla rostrata) and the alewife (Promolobus pseudoharengus) were taken with smelt but dissection proved no eggs or fry were present. It is suspected much fry is feed upon. This list of fish does not propose to cite all the predators of smelt but only to indicate a few of the most common ones.

Among the other vertebrates known to prey on smelt is the Atlantic harbour seal (Phoca vitulina concolor). It is common along the coast at all times of the year, but most abundant during the winter months. The author has a record of two of these seals venturing into the Bay area up to the dam in Newmarket. The food habits of the herring gull (Larus argentatus) were not throughly studied. However, observations indicate smelt are taken. Many herring gulls congregate in the shallow waters where smelt are known to be. With the aid of field-glasses, it appears the younger fish are taken.

A nematode parasite, probably of the genus Porrocaecum, was found to be the most conspicuous invertebrate enemy of the smelt. Copepods, which are the most common parasites upon the gills of fresh-water smelt, were not found in any of the marine smelt. On March 22, 1949, out of 43 smelt examined 22 were infected with one or more nematodes. Four was the most found in a single fish. These nematodes average about 55 millimeters in length with females predominating by a large margin. A conservative estimate of nematode infection for all the smelt examined would be about eight percent.

eight percent.

Ordinarily these nematodes are found encysted in the upper part of the back during early winter. About the start of the spawning run they are found all over the body, especially in the region of the central line. This parasite is more opaque then the fish and when held up to the light is readily seen. The smelt serves as a secondary host. The definitive host was not determined but the harbour seal along with other fish eating animals is suspected.

Jackson (1949) concerning parasitism states:

> "During the early part of the biological survey of Great Bay, when smelt fry were available in large numbers, it was noted that from 30 to 40 per-cent were parasitized; there being as many as six or seven parasites in some fish. These parasites we thought to be larval nematodes. It was not determined how fatal they were to the fish".

Timely and valuable additional information on the parasite involved is in the form of a letter from Mr. D. M. Scott, dated May 10, 1949. Mr. Scott is presently associated with the Fisheries Research Board of Canada; Atlantic Biological Station; St. Andrews, N.B. His letter in part reads:

> "For the past three years I have been studying the life history of an ascarid which occurs in many species of marine fishes including: smelt Osmerus mordax, cod Gadus callarias, eelpout Macrozoarces americanus and several other species. I have identified the worm as Porrocaecum decipiens Krabbe 1878 (=Ascaris lapsilaria Rud. 1802). My knowledge of the details of the life cycle is still incomplete but certain aspects of it have been established beyond doubt. All the worms present in fish are larval and they mature in the stomach of seals and, possibly, porpoises. The eggs are laid in the seal's stomach and pass out in the faeces. I am uncertain about the first phase of development but I suspect that there is an invertebrate host involved. The cycle may be shown as follows:
>
> Seal (mature worms) ⟶ eggs ⟶ Invertebrate host (?) ⟶ Fish (larval) ⟶ Seals

I am enclosing an appendix of bibliographic references which may be of some use to you.

Baylis, H. S. 1916 - Some Ascarids in the British Museum, Parasitology, V. 8, p. 360.

1920 - On the classification of the Ascaridae. (1) Systematic Value of Certain Characters of the Alimentary Canal. Parasitology, V. 14, p. 253.

Krabbe, H. 1878 - Saelernes og Tandhvalernes Spolorme. K. Dansk. Vidensk. Selsk. Forh. 1 43-51.

Martin, C. 1920 - Uber Ascariden larven aus dem Fleische von Seefischen. Z. Inf. Kr. kh. Haustiere, 22 13-36.

Stiles, C. W and Hassall, A. 1899 - Internal Parasites of the Fur Seal. U. S. Rep't Fur Seal Investigations, Washington, Pt. 3, pp. 99-177.

A small marine leech was found only once attached to a smelt. It left no mark on the smelt, nor did it appear to do any apparent harm. This leech resembled those commonly attached to smooth flounder in large numbers.

10. Effects of Pollution and Overfishing

Pollution as used here shall include the various deleterious substances which have gotten into the water from all sources. This included physical pollution such as finely divided silts and sediments, chemical or industrial pollution, and bacterial pollution which has a tendency to be overemphasized but perhaps not a greater factor than the first two mentioned.

Silt pollution especially as it applies to filling in spawning areas together with industrial pollution are the in spawning areas together with industrial pollution are the

more important problems. Smelt are known to tolerate considerable sewage and trade wastes in passing up stream to spawn in cleaner waters or less polluted tributaries. An example of this is in the Charles River in Cambridge, Mass., where smelt are found passing through these highly contaminated waters. Our own Exeter River, with its heavy industrial and sewage wastes, is known to have a smelt-spawning run as far as the dam which is above the concentrated pollution area when the tide is low. All smelt eggs found here were dead however. In spite of being deposited in considerably cleaner water the tide in backing up sweeps the potent wastes over the area causing the killing of the spawn.

All the eggs found this season were deposited over and stuck to the surface of smooth, clean, solid materials such as rocks, bricks, and gravel. Eggs of the smelt are adhesive and such surfaces are needed if they are not to be jeopardized by being carried with the current and smothered in flocculent materials.

The evidence is quite positive in regard to the silting in of spawning beds as shown by Jackson (1949).

> "In the Oyster River in the spring of 1940, following a heavy freshet which washed the rocks clean, as many as thirty or forty eggs were counted on one square inch of smooth rock surface following a spawning run of smelt. In more recent years these beds have become covered with slime and silt deposits. No eggs were found in 1945, 1946, or 1947 and it seems certain that, if deposited, they would have sunk into the accumulated sludge, and sewage deposits and besmothered. In the Oyster River, the drop in numbers has been closely correlated with the accumulation of sewage so that within the past six years commercial fishing has yeilded only poor returns".

The spread of Zostera in the various rivers and portions of the Bay, as presented in Part III, has helped some in controlling the silting problem. With the continued spread of the Zostera it is believed silting action will continue to decrease. Tidal actions keep this silt in circulation by its constant change in direction. It must be kept in mind that an abundance of eelgrass will never be a cure-all in as much as this silt material is being washed from cultivated fields and from forest areas following unrestricted lumbering.

Indication of the sewage pollution in Great Bay area can be determined by the number of coliform organism found in water under examination. Escherichia coli, Aerobacter aerogenes, and other coliform bacteria grow and multiply only in the elementary tracts of man and the higher animals. When found in the Bay it means it has arrived there by means of a relaxing sphincter.

The number of Coliform bacteria in the Bay is given by Jackson (1944) as shown in table 3. Since no appreciable cleanup has been initiated since that time, it can be assumed pollution has held its own or even increased for the general population certainly has. When it is understood that the U.S. Public Health Service stipulates no clams or oysters may be taken out of waters having over 70 coliform bacteria per hundred milliliters of water, our sewage problem shows its serious aspects.

So much sewage enters Great Bay that dilution with

Summary of Bacteriological Work on the Waters of Great Bay and its Tidal Rivers

Area	Sq. miles studied	Population	No. of samples	Est. No. of samples 1939	Average M.P.N. coliform bacteria per 100 milliliters of all samples taken
Salmon Falls River	324	17,000	29	255	3,286
Cocheco River	130	31,800	56	454	10,634
Upper Piscataqua (to Dover Pt.)			22	209	767
Lower Piscataqua (Dover Pt. to Interstate bridge		35,000	3	420	2,460
Bellamy River	40	3,000	62	559	1,573
Oyster River	14	3,500	83	766	803
Lamprey River	99	7,700	4	459	2,895
Exeter River	168	8,800	22	201	9,020
Lower Little Bay (Dover Pt. bridge to Fox Point)			43	413	108
Upper Little Bay (Fox to Adams Pt.)			35	302	87
Great Bay (West of line, Woodman to Weeks Pt.)			129	747	144
Greenland Bay (East of above line)			85	495	120
Fabyan Pt. to Pierce Pt. East			11	63	20
Total		520	4451		

*Inconclusive

The above data was accepted most cordially by the State Board of Health, The Biological Institute and the U. S. Public Health Service

Table 3. Indication of sewage pollution in Great Bay as illustrated by coliform bacteria counts.

sea water is a minor factor. The salinity of our rivers approaches that of Great Bay which is similar to the open sea (34 to 36 parts per 1000). ZoBell (1946) concerning this writes:

> "Sea water is neither anticeptic nor inimical to E. coli, sewage discharged into the sea is rapidly purified by sedimentation, predatory organisms, and dilution.
> The general absence of coliform bacteria in the sea except in areas known to be polluted with sewage confirms the validity of the test for coliform bacteria as an indicator of sewage pollution. It follows that, wherever large numbers of E. coli are found in the sea, the possibility exists of typhoid, dysentery, and cholera organisms also being present. Although epidemics of these gastro-intestinal diseases have never been traced to bathing beaches, outbreaks of typhoid have been traced to infected oysters."

The smelt provides a fishing that can be readily over-done. Its anadromous nature exposes it to probable anihilation by injudicious use of nets in the rivers unless restrictions are imposed. Weirs are the most destructive method of fishing during the spawning run of smelt. The other major types of fishing carried on at the present time are bowmetting and the use of hook and line. Not a single record is known of a drag sein being used the past season. Reason for this is because smelt have been depleted to such a point that no one considers it's worth the time and gear involved.

The lack of proper spawning grounds coupled with overfishing during the breeding season creates a situation very few fish can challenge. Kendall (1926) states:

> "The total depletion of the smelt fishery in some localities are attributed to one or more, and in some instances perhaps to all of several causes;

some instances perhaps to all of several causes;

which may be classified, at least in part, as follows: (1) Interference with reproduction: (2) excessive and wasteful fishing. The first class comprises obstruction and pollution of streams formally frequented by smelt for breeding, and uncontrolled fishing during the runs in the streams at spawning time. The second principally involves destruction of immature fish in the course of legal net fishing during the open season".

Dramatic confirmation of what can happen when a fishery is carried to an extreme is exemplified by Massachusetts sad mistake in allowing striped bass to be netted in the Parker River. It is reliably reported by their coastal wardens that in 1930, when netting was first allowed, over 60 tons of striped bass were taken out. This cut down the population to such a critical point that three years later less than a ton were netted. The law allowing this wholesale destruction was repealled too late. To the present day, the striped bass have failed to stage a comeback.

V. MARINE SMELT FISHERY IN GREAT BAY.

There appears to be a steady falling off in the smelt fishery during the past four or five years. An indication of this decline is shown by a similar decline in the sale of fishing licenses, sold in many cases for use only for smelting. For example, 325 licenses were sold in 1948 compared to 102 in 1949 by the Sporting Goods Store in Newington, N.H. These figures taken from the N.H. Fish and Game Department file, may not be all conclusive but certainly show the downward trend.

At best, the present fishery can be regarded as a sick resource. No longer do people speak of tons of smelt, but rather of pounds. The hook and line fisherman do not hope to fill their "kegs" any more, only hops to bring home a frying pan full. Even some weir fishermen this season have taken their netting down ten days before the season closed. Why? The fish just were not there!

1. Localities

Very few localities are now fished for smelt in the fall with hook and line. With a greater population, it is suspected they could be taken from every river and outlet all around the Bay region as in former years. The following are the only areas known where fish were hooked this past season: 1. Mouth of Beard's Creek in Durham; 2. Crommet Creek, Durham; 3. Mouth of Winnicut River, Greenland; 4. also at the mouth of Piskaring Brook in Greenland.

also at the mouth of Piskaring Brook in Greenland.

When the ice formed some poor bownet fishing was had in the Oyster and Exeter River. No bownets were set in the Lamprey River. A few smelt were taken by hook and line from the Exeter River. This method of fishing through the ice was not tried on the Lamprey or Oyster Rivers. The favorite spot for hook and line fishing is on Greenland Bay. The smelting here was the worse in the memory of the natives, and many did not care to fish after one or two fruitless attempts.

State regulations restrict net fishing only to the west side of the Bay. No weirs were in operation on the Oyster River. Two weirs were fished on the Lamprey and nine on the Exeter.

2. Fishing Season and Regulations

The legal closing of the marine smelt season in New Hampshire, from April twentieth to July first, does not cover the spawning period nor protect the breeding fish. To be effectual, the fishing season should be shortened at least 30 days, i.e. have the closed period start from March twentieth. Were this done, it would approach the wisdom of the neighboring states who have an earlier closing season with a corresponding more successful fishery than New Hampshire.

Massachusetts' laws pertaining to marine smelt read that all areas shall be closed from March fifteenth to May thirteenth, both dates inclusive. The rivers and brooks are carefully posted to this effect and a penalty is involved

for even walking in a brook if there is a chance of molesting the smelt. Maine similarly has regulations which provide better protection during the spawning season.

Fishery regulations for the Province of New Brunswick, Canada; where an intensive smelt fishery is carried on state:

> "No one shall fish for, catch, kill or sell smelt from the first day of March to the thirtieth day of June in each year, both days inclusive."

This law for the protection of the smelt appears as section 19 in the paper "Special Fisheries Regulation for the Province of New Brunswick" made by Order in Council P.C. 5357 dating December 31, 1947. Most of the smelt that appeared on the Boston market this year, and many times advertised as Great Bay Smelt, were shipped from New Brunswick.

In this state the only other regulations pertaining to the salt water smelt fishery, beside requiring an ordinary fishing license, are as follows and taken from the latest fish and game laws sections 57-58 pp. 73:

> "Salt Water Smelt. No person shall take salt water smelt from the Piscataqua river and its tributaries, the Exeter river and its tributaries, and Great Bay and Greenland Bay, from April twentieth to July first. Salt water smelt may be bought and sold during the open season therefor."
>
> "Nets; No person shall use or have in use a seine, weir, or net for the taking of smelt in the Piscataqua river and its tributaries, easterly of an imaginary line drawn from the easterly end of the Portsmouth and Concord bridge to Adam's Point in Durham."

3. Methods

In the past season, three chief methods of taking smelt have been employed: 1. hook and line, 2. bownets and

smelt have been employed: 1. hook and line, 2. bownets and

3. weirs. A fourth method employed in the past is the use of the drag seine. This was not used this year on the Bay but tried without catching any in Hampton Harbor, N.H.

Before the ice "makes" in the autumn, and again in the spring, "open water" fishing is carried on chiefly with hook and line. The gear used is usually a long bamboo rod, a piece of cord to the end of which is attached a brass wire spreader shaped like the letter "A", and snelled hooks baited with shrimp. Some connoissers use clam worms for bait, while others prefer young killifishes (Fundulus), garden worms, bits of red meat, dyed red frog legs, and cut up smelt. Any light rod can be used and it is known smelt will strike small scarlet flies. The angling aspect in this fishery has been sadly neglected.

When the Bay freezes over we have the advent of "bob houses". These vary from crude shacks to palatial huts. In past years hundreds of huts could be counted on the ice with several hundred fishermen engaged at one time. Not more than 60 houses were seen this year at any time, and these were towed to shore after fishing because of the exceptional poor ice conditions.

The houses are placed over channels varying in depths up to 30 feet. This jigger fishing essentially consists of a fishing line outfitted with a spreader to accomodate up to four hooks and attached to a stock. Lines can be fastened also to a board overhead in such a way that allows them to fall into the hole cut in the ice. When the

line twitches the fish is hauled in. Busy is the person who is operating several lines at one time when fish are biting. The better catches were made at the turn of the tide with some claiming night fishing to yeild more.

Bownet fishing starts when the rivers, where netting is allowed, are frozen over. These nets are about ten feet across the mouth and are lowered into the channel through a large rectangular hole cut in the ice for this purpose. Fishermen rarely fish over three hours at a time. Nets are put in twice a day at the change of tides. Often better catches are made on the ebb tide rather than on the flow tide. These nets must be frequently withdrawn and the fish taken out. Every five minutes is not too often when fish are running. No bownets used here now are known to have any traps incorporated to hold the fish when they enter.

A third and the most efficient means of taking smelt is the use of the weir. This type gear is usually set on the flats of the tidal rivers. In the Lamprey River during the past year they have been injudiciously operated more than half way across the river and over the Bay's best spawning area. This deplorable mean of fishing should be corrected. The largest catch recorded was made by one of these weirs when on March 28, 1949, 625 pounds of smelt were taken during two tides.

Figure 6 pictures a weir all set up and actually catching fish. It will be noted the trap is anchored so that changes of current do not alter the position of the gear.

Figure 6. A general view of a Great Bay tidal river weir set up for the taking of smelt.

Weirs are arranged so that the smelt coming in contact with the "leader", lead along it into the trap or box which is usually located in deeper water. In the event smelt should miss the weir on the way upstream, the chances are better than even of being caught coming back downstream.

4. Fishing Conditions and Catches

The smelt fishing can be reported from poor to no fishing at all. A good catch for bamboo pole fishing was ten fish. More often, no smelt were taken. Tomcod usually are active and biting at this time in the Bay which holds the fishermen's interest. Many localities were tried along the Bay by the author as well as other fishermen with no success.

Bob-house fishing was just as spotty. Well over a hundred holes were fished some days without a smelt taken. The last time this writer attempted fishing with two friends, a combined fishing time of 15 hours resulted in catching one smelt.

With the exception of February 12, 1949, when about 55 fishermen caught an estimated 1250 pounds of smelt, ten pounds was considered a large catch. The next day was a Sunday, the word got around, and over 150 people came to try their luck. The fishing was poor this day. The entire area in Greenland Bay was observed all morning. By early afternoon, the largest catch was six smelt.

The ice froze sufficiently to allow fishing on February 6, 1949, and the first smelt to be taken in Greenland

Bay was on February 8, 1949. On February twentieth it rained all evening causing the last patch of ice to leave Greenland Bay on February the twenty-fourth. Thus concluded the poorest fishing season on record for the "hookers".

An estimate for the entire season's catch on Greenland Bay, derived from a careful check of the area each day is 200 pounds. This figure excludes the exceptional catch of February 12, 1949.

Bownetting yeilded poor returns. Several smelt were taken in a few attempts on the Oyster River. The Lamprey was not bownetted. Two fishermen are known to have taken 27 pounds in one tide on the Exeter River. With better ice conditions, perhaps more would have been caught.

Weir fishing accounted for more smelt taken then all the other methods combined. The cleanest river, the Lamprey, provided the best fishing. The Oyster did not support a weir this season. The Exeter is the only other river where weirs were operated.

By March 15, 1949, the first weir was set up in the Lamprey River. In the Exeter River, nine weirs were soon in operation also. Approximately 36 days were fished by 11 weirs. The catches were far below those of previous years. These weirs were checked practically every day, at least during one of the low tides, when they were emptied of their fish. It is conservatively estimated 10,000 pounds of smelt were taken which computes to about 900 pounds per weir. The 1949 fishing was so poor, according to the standards of former years, that

four weirs on the Exeter River were dismantled on April 10, 1949, while over a week of legal season was left in which to fish. The Lamprey River is estimated to have produced 6000 pounds of smelt and the Exeter River 4000 pounds.

VI. SUMMARY

1. The drainage system of Great Bay is approximately 700 square miles.

2. There are eight tidal rivers with a total length of 33 miles. Both Bays cover an area of about 5540 acres. The total shore line computed at high tide level is 110 miles.

3. Eelgrass (Zostera) has made a remarkable come back since its almost total disappearance in the early 1930's. Zostera is restricted to the tidal rivers and the western side of the Bay.

4. The smelt fishery still accounts for the most important economic product of Great Bay and its tributary rivers.

5. Greenland Bay, the Exeter and Lamprey Rivers seem to be the waters most frequented by smelt.

6. Smelt examined ranged from 55 to 274 millimeters in total length.

7. The food of smelt varies with its age; smaller smelt are able to use plankton, which the larger smelt depend on various small fishes and shrimp.

8. Plankton in Great Bay is abundant.

9. Of the 1445 smelt sample taken during the period between March 17, to April 15, 1949, from weirs in the Exeter and Lamprey Rivers, 906 were males and 539 were females. This represents a male/female ratio of 1.709.

10. It has been proved that smelt will return for spawning to the original stream in which they were spawned or hatched from eggs planted.

11. Smelt spawn was found in only two stations: 1. All dead below dam in Exeter and 2. as many as 72 eggs to the square inch below dam in Newmarket(in good condition).

12. Information on early life history of the smelt in Great Bay is fragmentary.

13. Four year old smelt predominated in the "bob-house" fishery, followed by the three year olds.

14. It was determined 1 year old fish averaged 74.0 millimeters, 2 year olds 145.0, 3 year olds 171.0, 4 year olds 220.0, and 5 year olds 240.0.

15. Egg counts were made for all age groups. In thousands of eggs, 2 year smelt averaged 8.1, 3 year olds 16.1, 4 year olds 28.2 and 5 year olds 50.9.

16. Various species of fish were found to be predators of smelt and their eggs.

17. A nematode parasite, probably Porrocaecum decipiens, was found to be the most conspicuous invertebrate enemy of the smelt.

18. Silt and results of industrial pollution have ruined many spawning areas.

19. Lack of proper spawning grounds, coupled with overfishing during the breeding season, is rapidly cutting down the population.

20. The legal closing of the marine smelt season in N.H. from April twentieth to July first, does not cover the spawning period nor protect the breeding fish.

21. In the past season, three chief methods of taking smelt have been employed: 1. hook and line, 2. bow-nets, and 3. weirs.

22. Certain weirs have been injudiciously operated more than half way across the river, and the most successful weir over the Bay's best spawning area.

23. It is conservatively estimated 10,000 pounds of smelt were taken by weirs, 6000 on the Lamprey and 4000 on the Exeter River for the 1949 season.

VII. RECOMMENDATIONS

From the data presented, it would seem the entire problem of increasing the smelt population in Great Bay involves cleaning up pollution and protecting breeding fish. Anything done to improve the smelt fishery also improves the general productivity of this whole area. The problem of cleaning up the pollution is a long range proposition which will take more time than we need wait before smelt improvement be initiated. With these thoughts in mind, then, it is recommended:

1. To continue the study and investigation of the fishery for there is still much this paper does not attempt to cover.

2. Legislation be enacted to protect the smelt when they need it most, during the critical spawning period. As previously suggested, closing the smelt fishing season 30 days earlier (at least) is strongly urged.

3. Help in the work of the State Water Pollution Board, Public Health Service, etc., in encouraging the cleaning up of industrial wastes and sewage.

4. An attempt be made to artificially hatch smelt in rivers and brooks which currently provide suitable hatching areas. Eggs for this purpose can be readily had from neighboring areas. Massachusetts, it is believed, would be willing and able to supply some eggs. The Oyster River after some preparation such as cleaning up the rocks, introducing clean

gravel, etc., should be one of the first areas where this egg introduction be attempted. The Winnicut River, Pickering Brook and other suitable areas in Greenland and Newington should likewise have eggs introduced on an experimental basis.

5. At least one brook should have smelt introduced and prevented from escaping by means of a net so that observations can be made as to their spawning. This method has been successfully used to induce other species to spawn in a given area thus establishing a spawning run. The above two methods should establish smelt where presently none are known to spawn.

6. Study the possibility of operating a small hatchery during the period when breeding fish would be available for stripping. This same hatchery could be used to increase the supply of striped bass, white perch, and perhaps some member of the salmon family.

7. Attempt to establish Zostera on the eastside of Great Bay to help control silting.

8. Construction of fishways over the dams. Tentative plans have already been drawn for a fishway over the Oyster River dam. It is hoped this dam interest will continue and funds can be allocated to realize this fine conservation measure.

SOUTH BERWICK
ROLLINSFORD
SOMERSWORTH
DOVER
DURHAM
NEWINGTON
PORTSMOUTH
GREENLAND
NEWCASTLE
RYE
NEW CASTLE
GREAT EAST
BOUNDARY LINE
MAINE
NEW HAMPSHIRE
PISCATAQUA
STRAFFORD CO
YORK CO
ROCKINGHAM CO
SALMON FALLS
COCHECO
BELLAMY
LITTLE BAY
GREAT BAY
OYSTER RIVER
BACK RIVER
LITTLE HARBOR
Salmon Falls
South Berwick
Rollinsford
Dover
Durham
Newington
Portsmouth
Greenland
Rye
Newcastle
Great Bay
Little Bay
Oyster River
Bellamy River
Back River
Piscataqua River
Salmon Falls River
Cocheco River
Maine
New Hampshire

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